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REPORT RESUMES

ED 003 657 56
INTRODUCTION AND STATIC ELECTRICITY, VOLUME 1.
BY- KLAUS, DAVID J. AND OTHERS
AMERICAN INST. FOR RESEARCH IN BEHAVIORAL SCIENCES
REPORT NUMBER NDEA-VIIA-337-VOL-1 PUB DATE 60
REPORT NUMBER AIR-310-RP-60-1-1-2-3
GRANT OEG-736022-90
EDRS PRICE MF-$0.90 HC-$23.08 577P.

DESCRIPTORS- PROGRAMED INSTRUCTION, *AUTOINSTRUCTIONAL AIDS, *PHYSICS INSTRUCTION, *MATERIAL DEVELOPMENT, *TEXTBOOK PREPARATION, EXPERIMENTAL PROGRAMS, *PROGRAMED MATERIALS, PITTSBURGH, PENNSYLVANIA

THIS VOLUME, PART OF A TWO-VOLUME SET, PROVIDES AUTOINSTRUCTION IN PHYSICS. THE MATERIAL COVERS UNITS ON (1) STATIC ELECTRICITY AND ELECTRICAL CHARGES, (2) COULOMB'S LAW, (3) DISTRIBUTION OF CHARGE AND FLOW OF CURRENT, (4) DIFFERENCE OF POTENTIAL, (5) BATTERIES AND CIRCUITS, (6) RESISTANCE AND RESISTORS, (7) POTENTIAL DIVIDER AND WHEATSTONE BRIDGE, (8) ELECTRICAL FIELD AND CAPACITANCE, AND (9) ELECTROSTATICS AND ELECTRIC CURRENTS REVIEW. VOLUME 2, ED 003 659, PRESENTS UNITS ON REFLECTION AND REFRACTION OF LIGHT. (RS)

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VOLUME 1

start →
INTRODUCTION & STATIC ELECTRICITY

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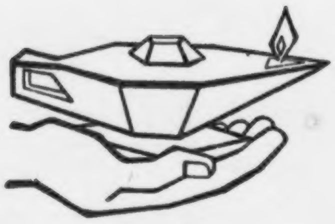
The development of these materials was supported by Grant Number 736022.90 from the United States Office of Education, Department of Health, Education, and Welfare, under Title VII of the National Defense Education Act of 1958. These self-instructional materials were developed at the American Institute for Research under the direction of Dr. David J. Klaus. Portions of these materials were prepared by Ernest S. Holmok, Diane S. Meyer and Arthur A. Lumsdaine. Dr. Karl S. Quisenberry of the Department of Physics, University of Pittsburgh, served as technical consultant. Dr. Arthur A. Lumsdaine has been the over-all supervisor of the project.

These materials were prepared for use in an experimental study of the self-tutoring approach in education. Further information concerning the design of the study and the data obtained are contained in reports available from the American Institute for Research.



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DIRECTIONS FOR USING THIS BOOK

The pages of this book have been arranged in a special way. Here is how to follow along and do the steps in the right order.

As you start each unit, the steps will be along the top row of the pages. You should read step 1, write your answer, and then turn the page to see the correct answer on the following page. The answer to step 1 will also be at the top on the right-hand page. To see step 2, you should again turn the page, always looking at the top of the next right-hand page. You always have to turn to the next page to find the answer to a question, and then turn the page again to go on to the next question.

Each unit begins and ends with a yellow page. When you get to the last page of the unit, you will see directions telling you how to turn the book around and go on with the next step.

Altogether, there are five rows of steps on each page. You should only pay attention to the steps in the row you are working on.

Once you get started, you will find it is easy to follow along properly. Just be sure you do the steps in their proper order. Each step has been numbered to help you. The question for each step is numbered with a capital letter (like A-27) and the answer for that step is numbered with a small letter (like a-27).

Remember, after answering each question, turn the page to see the answer, and then turn the page again to see the next step.

Do not try to do too much at one time. You will make fewer errors and remember more of what you have learned if you stop and relax every once in a while.

INSTRUCTIONS TO THE STUDENT

You are going to work with a new way to provide instruction in subjects like physics. Educators have been working very hard to invent methods for making learning easier and faster. The material you will work with is based on one of these new techniques. You will discover that it is quite easy to master physics with these materials if you follow the instructions carefully and let the material do much of the work for you.

Many students have already used these kinds of materials to learn physics and several other subjects. They found learning was surprisingly rapid and thorough. You will soon find yourself learning new facts faster than you thought you ever could. You will find that physics is very interesting, and that as you know more and more about it, you will understand many things that you really didn't understand before.

To really understand physics you have to understand each principle or fact as it comes up. These materials are arranged to give you the information you need in the best possible way. Each new principle or fact will be carefully explained and then you will be given some practice using the information you already have before going on to the next principle. In this way, you will quickly learn all the important things, even those that are very complex.

The material has been organized into small steps. In physics, of course, there are a large number of these steps, but if you take them one at a time you will soon have mastered all of them.

Each step is something like a question, but this is *not* any kind of a test. Instead, the steps are to help you develop knowledge about physics and help you practice what you know. You will not be graded on how many steps you get right or on how fast you go. There is no reason why you have to be correct with your answers to all the steps. If you try, you will find you *are* right most of the time and that you are actually learning a great amount of physics.

Each step, as was said before, is something like a question. Your job is to look at each step in turn and give the best answer you can. You will know what kind of answer to give by first reading the whole step and then going back to fill in the blanks. A blank looks like this: ☐. Every time you come to a box like this one, you are to fill in the missing word right in the book. Only a few of the questions will be very difficult. For most of the steps, if you read the question carefully you will be able to give the correct answer without any trouble at all. Now let's try a step. Look at this one, read it carefully, and answer it by giving the missing word.

> *Physics* is the branch of science that deals with the way nonliving things act under certain conditions. The way a pendulum swings or a gasoline engine operates or a radio produces music are all examples of what is studied in ☐.

That was an easy step. The correct answer was the word PHYSICS. This was the missing word represented by the box. If you did not give the correct answer, go back and read the question again. You should do this any time you get a wrong answer; reread the question so that you understand the fact or principle involved before you go on. If necessary, go back and read a few of the preceding questions.

Every step is important and you should not try to skip any. If you try each step in turn, you will be sure to learn everything you have to know. Now try the next step. Be sure to read the question carefully; it has two missing words in it.

> The branch of science that deals with the way nonliving things act under certain conditions is called [   ]. Sometimes, instead of saying "nonliving" we use the word "inanimate." An [   ] object is a nonliving object.

This step was a little more difficult. The two answers are the words PHYSICS and INANIMATE. If you got either one wrong, look at the step again. You can also go back and read the first step again, if this will be of help.

In the next step, there will be a box with a star in it that looks like this: [*   ]. This means that two or more words are missing and that you have to give all the missing words for your answer to be correct. Go ahead and try the next step. Remember, a box with a star in it means that more than one word is missing.

> Physics deals with inanimate objects. A pendulum, a gasoline engine, and a radio are all examples of [*   ].

The answer for this step is INANIMATE OBJECTS. If you did not give both of the missing words, go back and read the step again. Sometimes, a step would be too difficult if we did not give you a clue as to what the correct answer could be. For steps like this, we will put the words you could choose from in parentheses like this: (large/small) [   ]. Whenever you see parentheses containing two or three words, separated by slashes and appearing just before a box, you know one of those words is the correct one. Never use any other words in a case like this. The missing word will always be one of these in the parentheses. Now try the next step.

> The word "animate" means "living" or "alive". Biology, therefore studies (animate/inanimate) [   ] things while physics studies (animate/inanimate) [   ] things.

The two answers for this step were ANIMATE and INANIMATE, in that order. This step is also an example of another important point. Scientists often use special, technical words when they want to say something. It is important for you to use the correct word also. Whenever you think of two words that could be the correct answer, try to use the one physicists would use. The correct technical word is always better than the more common word with similar meaning. In the next step, there are two boxes to fill in. Always try to use the best word you can think of to complete the step.

> While you have learned that physics deals only with _____ objects, it sometimes deals with animate things as well, but treats them as if they were not living. For instance, physics is concerned with how animals make noises and how birds fly. The principles a physicist uses in these studies, however, are the same as those he ordinarily uses for *_____ .

The two answers for this step were INANIMATE and INANIMATE OBJECTS. Read the step again if you got either of them wrong. For the first answer you could have used the word "nonliving" but this would not have been as good as "inanimate". To show you some other word is also correct, but not as good, the answer will look like this: "inanimate (or, nonliving)". When you see an answer like this, you know the first word was best and while the second word is also correct, it is not as good. Always try to use the word a physicist would use. Write your answer right in the book, either in the box or below the question. Try this step.

> Some sciences are called exact sciences. If we begin to heat water in a physics experiment we know exactly at what temperature it will boil, but if we plant a seed for a biology experiment we (do know/ do not know) _____ exactly how many leaves the tree will have. Physics is called an _____ science but biology is not called an *_____ .

The answers to this step are DO NOT KNOW, EXACT, and EXACT SCIENCE. As you can see from what you have already learned, it is very important to do each step in order. The steps have been arranged to make learning as easy and as fast as possible. Sometimes you will have a temptation to peek ahead. Try not to. If you work steadily, you will soon get through the whole unit. When you look ahead, you may become confused. These materials are written in such a way as to help you learn the best possible way. You will learn the most from them by doing each step in order. It is best if you don't look ahead. Now try this step.

> Because we can make very accurate predictions of what will happen in a physics experiment, we call physics an _____ science. Physics, then, is an *_____ which deals with the way _____ objects act under certain conditions.

The answers to this step are EXACT, EXACT SCIENCE, and INANIMATE. If you missed any, read the step again. Sometimes you will still not see why the answer we give is the best one. If this happens, go back over some previous steps until you do understand. Unless you understand every point, it will be harder for you to answer the more complex steps correctly. Once you do understand a step which you first answered incorrectly, it is a good idea to read the whole step again, putting in the correct words. This way you will be well prepared for the steps that follow. Now try this step.

> Another way of looking at an exact science is that each time an experiment is done or repeated, we will get exactly the same results. Physics is an * ________ because we (can/cannot) ________ make very accurate predictions of what will happen in an experiment. We also call it an ________ science because each time an experiment is repeated we get the same ________.

The answers are EXACT SCIENCE, CAN, EXACT, and RESULTS. Sometimes we will want to have you give an answer in your own words. This will happen when we want you to finish a sentence. To ask you to do this we will use a box with two stars, like this: ** ________. When you see a box like this, you are to use your own words to complete the step. Sometimes only a few words will be necessary, but sometimes you will have to answer with a whole sentence. Each time, try to give as good an answer as you can. If your answer is long, you can write it beneath the question.

> Physics is an exact science because we can make very accurate predictions about what will happen in an experiment and because each time an experiment is repeated we ** ________.

The correct answer is GET THE SAME RESULT. For this kind of a step, you do not have to use exactly the right words to be correct, but your answer should mean the same as the answer we give. Nothing important should be left out of your answer; if you give only part of the answer you have not completed the step correctly. A box with two stars means you should use your own words and that the correct answer can be as long as a whole sentence. Remember, too, that your answer will be most correct if you use the words a physicist would use. Try this step.

> An exact science is one in which we get the same results from an experiment ** ________ and because we can make accurate predictions about ** ________. ________ is an example of an exact science.

The correct answers are EACH TIME IT IS REPEATED, WHAT WILL HAPPEN IN AN EXPERIMENT, and PHYSICS. There are just two more kinds of boxes. When you see a box like this: $\boxed{\#\ .\quad}$, it means a number is the correct answer. When you see a box like this: $\boxed{\$\quad}$, it means a symbol, such as a letter or plus-sign, is the correct answer. Physics uses a lot of symbols; they are a shorthand way of writing something. Try the next step, remembering the two new kinds of boxes. When you see either of these boxes, your answer is only correct if you use a number or symbol. Words will not be correct.

Measurements are very important in physics. One kind of measurement physicists use is temperature. Temperature is given in degrees. We abbreviate the word degrees with a little circle like this: 32°. This is the temperature, measured on an ordinary thermometer, at which water will freeze. Water boils at two hundred and twelve degrees which we write as $\boxed{\#\quad}^{\circ}$. The temperature inside our bodies is written as 98.6 $\boxed{\$\quad}$.

The correct answers to this step are 212 and °. For the second answer, be sure you used the symbol and not the word "degrees". Sometimes, we will want you to draw your answer or fill in a part of a picture or diagram. The step will tell you what to do. When you make a drawing, try to be as careful as possible, but you do not have to make it look pretty. You just have to have the right idea. The answer will show you the correct drawing. None of the drawings will be very difficult so do the best you can. Try the next step. Make your drawing right in the book.

There are two kinds of thermometers used in physics. One is a glass tube filled with liquid, as in Fig. 1. The other has a dial, as in Fig. 2. The thermometer in Fig. 1 shows a temperature of 80°. Draw a line in Fig. 2 to show about how it would look when it indicated 80°.

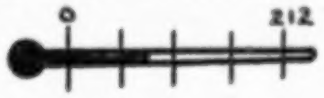


FIG. 1

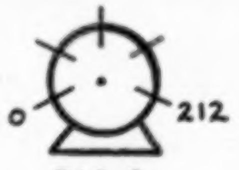


FIG. 2

To answer this step, you should have drawn a line like in Fig. A. The line in Fig. B is also correct even though it is wavy, but the line in Fig. C is wrong because it points to the wrong place on the dial. To be correct, a drawing should show the right idea but does not have to look pretty.

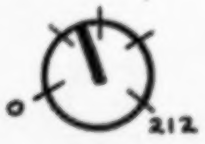


FIG. A

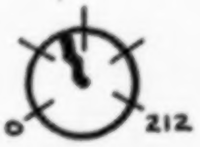


FIG. B

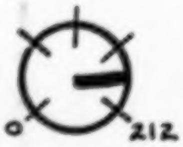


FIG. C

⑦

You have now tried all the kinds of steps and you are ready to learn physics this new way. To remind you of the important suggestions, here is a list:

1. This is not a test; it is a way to learn. Always try each step even if you have to guess. You will often be correct.

2. Read each question carefully. Don't make mistakes because you missed seeing part of the question.

3. Make sure you understand why each answer is correct. If you have to, look at previous steps to see if you missed something.

4. Try every step in order. Do not peek ahead. If you do, you will only slow down your own progress.

5. Write your answers in the book, either in the box or below the question. Use the words a physicist would use.

⑨ PRECEDING PAGE MISSING

X

SPECIAL UNIT: MATHEMATICS

The remainder of this book is a special section on mathematics. After you begin your study of physics using these new materials, you will want to try this special section. It will help you do many of the problems you will come to. Don't start this section now; wait until after you have begun one of the regular units in the course. By waiting until you have learned some physics this new way, you will find that the special mathematics section is more interesting to you, and it will be very easy to understand.

The section contains three parts:

Steps N1 - N33 contain some hints on arithmetic.
Steps N34 - N66 are on algebra and units of measure.
Steps N67 - N89 deal with angles and other points in geometry.

X ⑩

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

UNIT ENDS HERE

N-1

Physics is an exact science. For this reason much of physics is concerned with mathematics. All exact sciences, in fact, are concerned with [ ].

N-19

A digit is a single number, like 9 or 5 or 3. A number like 14 has two digits. The number 35 also has [#] digits. The number 138 has [*].

N-37

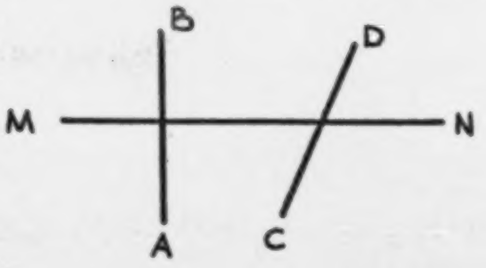
A symbol is used in a formula to tell you which numbers to use. The formula a + b = c has three [ ] standing for numbers.

N-55

If A = df and A = w - g, to find w, knowing d, f, and g, we would first say df = [$]. Then we would (add/subtract) [ ] g to both sides, giving us [$] = w.

N-73

In the figure, line AB is perpendicular to line MN, but line CD (is/is not) [ ] perpendicular to line MN.



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END OF UNIT

---

n-72

perpendicular

---

n-54

w-g

---

n-36

set of directions telling you what to do with certain numbers.

---

n-18

$$\begin{array}{r} 4.200 \\ .331 \\ \hline -\,3.869 \end{array}$$

(you must have the minus sign to be correct)

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⑬

n-1

mathematics

n-19

2
3 digits

n-37

symbols

n-55

v - g
add
df + g (=v)

n-73

is not

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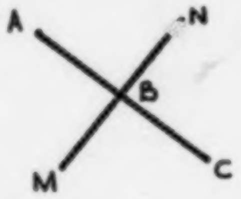
END OF UNIT

N-72

In this figure, line ABC is ☐ to line MBN.



N-54

If two formulas have a common term, we can substitute and make a new formula. For instance, if R = s + t and R = $\frac{m}{v}$, s + t = $\frac{m}{v}$. If A = df and A = w - g, we know that df = ☐ $.

N-36

There are a number of formulas (or, formulae) in physics. Every formula is a ☐ ** ☐.

N-18

Try this problem, and remember you will get a negative number:
0.331 - 4.2 = ☐ #.

(14)

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N-2

Mathematics is the use of numbers as tools. Just as a carpenter or electrician does his best work when he uses his tools properly, a physicist also does his best work when he uses ☐, which are his tools, properly.

N-20

To multiply when decimals are involved, remember that the answer should have as many digits to the right of the decimal point as there were in both numbers in the problem. For instance,

$$\begin{array}{r} 4.2 \\ \underline{\times\ 3.3} \\ 126 \\ \underline{126} \\ 13.86 \end{array} \qquad \text{and} \qquad \begin{array}{r} 3.6 \\ \underline{\times\ 4.1} \\ \boxed{\#\quad} \end{array}$$

N-38

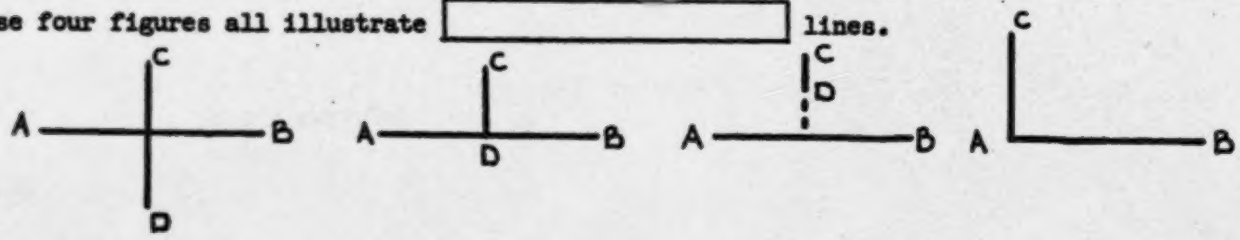
Usually only one symbol is used for any one particular kind of number. Often it is the first letter of the word it stands for. For instance, d is a ☐ which almost always means distance.

N-56

There are some formulas in science which require the use of a constant as one term in the formula. A constant is usually written in symbols as "k." In the formula A = G + k, for instance, A stands for age, G stands for grade, and k is a ☐.

N-74

When one line is perpendicular to another, the lines actually do not have to cross. These four figures all illustrate ☐ lines.



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n-89

right
right triangle

n-71

perpendicular
perpendicular

n-53

R

n-35

directions
numbers

n-17

24
$-\frac{5}{24}$ (you must have the minus sign to be correct)

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⑰

n-2

numbers

n-20

14.76

n-38

symbol

n-56

constant

n-74

perpendicular

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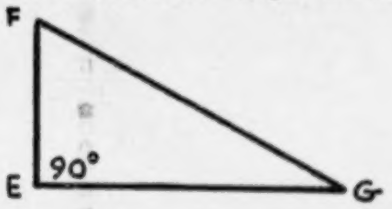
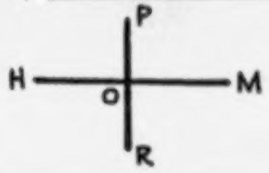
N-89

A right triangle is a triangle which has one 90° angle. We call such an angle a ☐ angle. The figure contains a 90° angle so it is a [*].



N-71

One line is perpendicular to another when the two lines form a cross (actually, when the lines are 90 degrees to each other.) In the figure, line HOM is ☐ to line POR, and line POR is also ☐ to line HOM.



N-53

Sometimes there are two formulas that each have the same term, as $R = s + t$ and $R = s + t$ and $R = \frac{m}{v}$. We could use either formula to determine the value of [$].

N-35

A formula is a set of ☐ telling you what to do with certain ☐.

N-17

You can also get a negative number when subtracting fractions. The lowest common denominator for $\frac{1}{8} - \frac{1}{3}$ is [#], and the answer is [#].

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N-3

Some of the mathematics used in physics is very difficult, but the mathematics you will use will be easy. To help you, we will give you some hints in arithmetic and algebra. Both arithmetic and algebra are kinds of ☐.

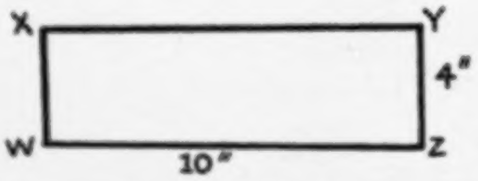
N-21

In this problem, there are a total of six digits to the right of the decimal point in the problem. You will have to add zeros to the left of the answer to get the proper number of digits in the answer.

$$\begin{array}{r} 0.001 \\ \underline{\times\ 0.002} \\ \boxed{\#\quad} \end{array}$$

N-39

The formula for area of a rectangle is usually given as A = bh. This means that area (A) equals the length of the base (b) times the height (h) of the rectangle. The area of this rectangle is $\boxed{\#\quad}$ square inches.

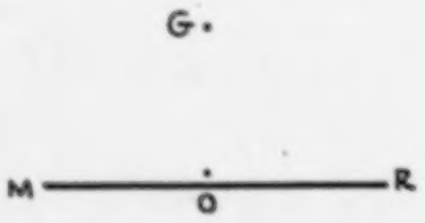


N-57

A constant is a number which is always the same when used in any one formula. In the particular formula A = G + k, k is always 5. Because k always remains the same in this formula we call it a ☐.

N-75

Draw a line perpendicular to line MOR from point G.



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n-88

B (90°)
A (30°)
C (60°)

---

n-70

HLJ
WXYZ

---

n-52

$H - K = L$ (or, $L = H - K$)

---

n-34

formula

---

n-16

-12

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n-3

mathematics

n-21

0.000002

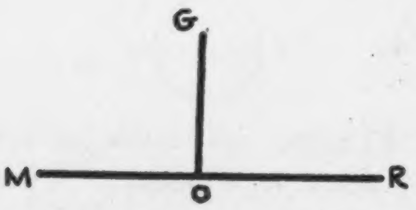
n-39

40

n-57

constant

n-75



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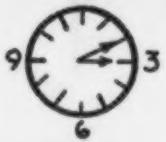
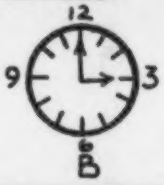
N-88

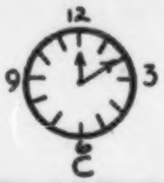
The hands of a clock form different angles as they travel around the dial. Figure $\boxed{\$\quad}$ shows a 90° angle formed by the hands. We might say that figure $\boxed{\$\quad}$ shows a 30° angle, and figure $\boxed{\$\quad}$ shows a larger 60° angle.



A



B



C

N-70

A shape is identified by several letters. Figure 1 shows triangle ABC, figure 2 shows triangle $\boxed{\$\quad}$, and figure 3 shows rectangle $\boxed{\$\quad}$.

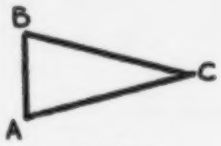


FIG. 1

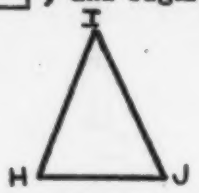


FIG. 2

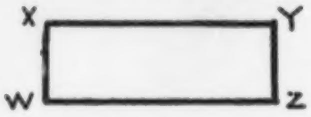


FIG. 3

N-52

If we had the formula H = K + L and wanted to find K, we would subtract it from both sides, or H - L = K. If we wanted to find L, we would write the formula as $\boxed{\$\quad}$.

N-34

A formula is a set of directions which tells you what to do with certain numbers. In mathematics, a set of directions is called a $\boxed{\quad}$.

N-16

Sometimes when we subtract we get a negative number. That means the number is less than zero. For example, 21 - 33 = -12 (say minus twelve.) We found this answer by subtracting the smaller number from the larger and using a minus sign with the answer. In the same way, 16 - 28 = $\boxed{\#\quad}$.

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N-4

Arithmetic includes adding, subtracting, multiplying, and ☐. To find a sum, we ☐ numbers and to find a product, we ☐ numbers.

N-22

To divide decimal numbers, such as 1.2 divided by 0.6, we proceed like this:

$$0.6\overline{)\dot{1}.2} = 0.6.\overline{)1.\dot{2}.} = 06.\overline{)1\dot{2}.} = 6\overline{)1\dot{2}.}$$

We move the decimal point over to the right of the number we divide by and an equal number of places in the number we are dividing into. In this example, 0.6 becomes 6., and 1.2 becomes [#], so the answer is 12 divided by 6 or [#].

N-40

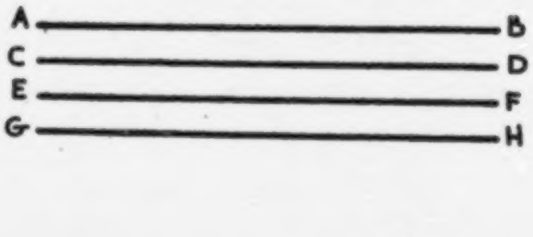
In the formula A = bh, A is the ☐ for area, and b is the ☐ for length of the base. We could write the formula in words as ☐ equals base times height.

N-58

In the formula A = G + k, k was always 5. In the formula $F = \frac{I}{k}$, where F stands feet and I for inches, k is always 12. In any one formula, k is always constant. This means the value of k [*].

N-76

Two lines which are parallel never will cross no matter how far we follow the lines. None of the lines in this figure will cross, so the lines are all ☐.



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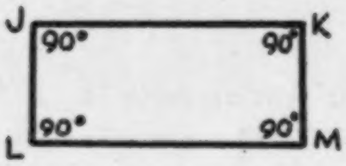
n-87

4


J
K
L
M
90°
90°
90°
90°

n-69

MNO

PQR

n-51

$\frac{P}{m} = s$ (or, $s = \frac{P}{m}$)

n-33

$\frac{1}{4} + \frac{1}{6} = \frac{5}{12}$

n-15

12

$\frac{5}{12}$

A·I·R ©1960

n-4

dividing
add
multiply

---

n-22

12.
2

---

n-40

symbol
symbol
area

---

n-58

never changes (or, is always the same)

---

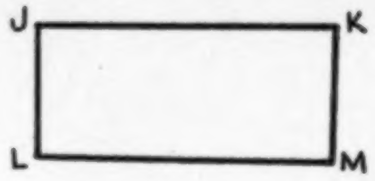
n-76

parallel

A·I·R ©1960

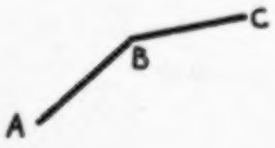
N-87

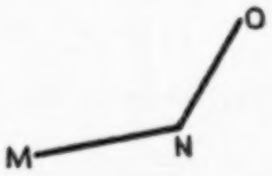
An angle of 90° is often called a "right angle." In the figure below, there are $\boxed{\#}$ right angles. Label each of them 90°.

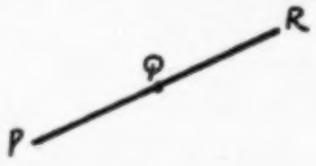


N-69

Sometimes we identify a long or crooked line by more than two letters. Figure 1 shows line ABC, figure 2 shows line $\boxed{\$}$ and figure 3 shows line $\boxed{\$}$.







N-51

In the formula P = ms, if we knew the value of P and s, but wanted to find m we would write the formula as $\frac{P}{s} = m$. If we knew P and m but wanted to find s we would write it as $\boxed{\$}$.

N-33

Find the sum of the reciprocals of these two numbers: 4, 6.

$\boxed{\$} + \boxed{\$} = \boxed{\$}$

N-15

In subtracting fractions, we also have to find the lowest common denominator before we subtract. The lowest common denominator for $\frac{9}{12} - \frac{1}{3}$ is $\boxed{\#}$, and the answer is $\boxed{\#}$.

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㉗

N-5

Find the sum of these numbers:

$$\begin{array}{r} 17 \\ \underline{+\ 29} \end{array}$$

$\boxed{\#}$

N-23

We would use the same procedure for this problem:

$0.4\overline{)\overset{\cdot}{0}.08} = 0.4.\overline{)\,0.\overset{\cdot}{0}.8} = 4\overline{)\overset{\cdot}{0}.8}$

The answer to this problem is $\boxed{\#}$.

N-41

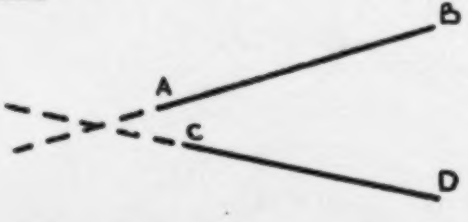
Using the formula A = bh, find the area of a rectangle when h = 4 and b = 5: A = $\boxed{\#}$. Similarly, if h = 3 and b = 6, A = $\boxed{\#}$.

N-59

The formula A = G + k tells you how to find the age of most students by knowing their grade in school. For instance, to find the age of a student in the third grade, we say: A = G + k, A = 3 + 5, A = $\boxed{\#}$. To find the number of feet in 36 inches, we say: $F = \frac{I}{k}$, $I = \frac{36}{12}$, I = $\boxed{\#}$.

N-77

The solid lines in the figure do not cross yet, but they would if we went to the left far enough, as shown by the dotted lines. The solid lines are not $\boxed{}$ lines because they $\boxed{*}$.



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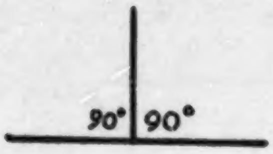
n-86



n-68

DF or FD

n-50

$(m) = \frac{W}{g}$

$(g) = \frac{W}{m}$

n-32

reciprocal

3

n-14

7.63

A·I·R ©1960

n-5

46

n-23

0.2 (the decimal point must be before the 2 to be correct)

n-41

20
18

n-59

8
3

n-77

parallel
will meet on a point (or, will cross)

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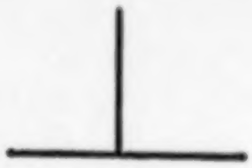
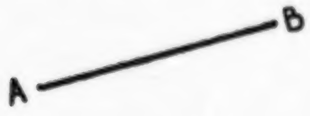
N-86

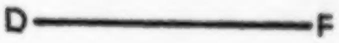
When one line is perpendicular to another, the angles formed are always 90°. In the figure, write in 90° to show these angles.



N-68

Figure 1 shows line AB, figure 2 shows line \$.





N-50

In the formula $G = hr$, we can divide both sides by "r," which gives us $\frac{G}{r} = \frac{hr}{r}$, and cancelling r's gives us $\frac{G}{r} = h$. If we divide each side of $G = hr$ by "h," we get $\frac{G}{h} = r$, or, $r = \frac{G}{h}$. Starting with the formula $W = mg$, rewrite it to show how you would find m: m = \$. Show how you would find g: g = \$.

N-32

Sometimes a formula involves the reciprocal of a number. To get the reciprocal of a number we make a fraction using the number as the denominator and "one" is the numerator. For instance, $\frac{1}{9}$ is the reciprocal of 9, and $\frac{1}{3}$ is the ☐ of #.

N-14

The rules for subtraction when decimals and fractions are involved are similar to those for addition. For example, 13.23 minus 5.6 is written as

$$\begin{array}{r} 13.23 \\ \underline{-\ 5.60} \\ \# \end{array}$$

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N-6

Sometimes, a problem looks hard because it is long. If you are careful, however, it will be as easy as a very short problem. Find this sum:

$$\begin{array}{r} 39715 \\ +\ 42263 \\ \hline \end{array}$$

☐

N-24

Many times, a division problem that looks difficult can be simplified by cancelling zeros. For instance, 18000 divided by 9,000 is the same as $\frac{18,\cancel{000}}{9,\cancel{000}}$ or 18 divided by ☐, which equals ☐.

N-42

With the formula A = bh, if we know the area of a rectangle and the height of the rectangle, we can find the length of the base. If A = 18 and h = 3, we can substitute in the formula, 18 = b3, or b = $\frac{18}{3}$ = ☐. Similarly, if A = 28 and h = 7, b = ☐.

N-60

A constant in a formula is usually indicated by the symbol ☐. It stands for a particular ☐, like 5 or 12, which is always the same for any one formula.

N-78

The lines in figure 1 (are/are not) ☐ parallel. The lines in figure 2 (are/are not) ☐ parallel.

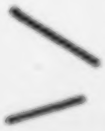

FIG. 1

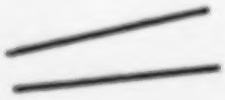

FIG. 2

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n-85

90°

---

n-67

AC or CA

---

n-49

$(P + q) = kmR + q$

---

n-31

30

---

n-13

12

$\frac{11}{12}$

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㉟

n-6

81978

---

n-24

9
2

---

n-42

6
4

---

n-60

k
number

---

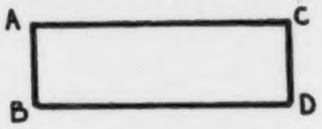
n-78

are not
are not

A·I·R ©1960

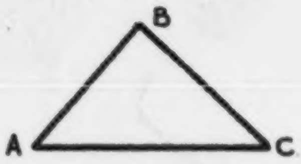
N-85

The angles in a square or rectangle are always 90 degrees. We abbreviate "degrees" with the symbol $^{\circ}$, as 30°, 60°, etc. In this figure, there are four angles of $\boxed{\#\quad}$ $\boxed{\$\quad}$ each.



N-67

The last point to cover is how to use a diagram or figure. This is a diagram of a triangle. We identify the sides of the triangle by letters. The three sides are AB, BC, and $\boxed{\$\quad}$.



N-49

In general, we can always add the same thing to both sides of a formula. Add a "q" to both sides of this formula: P = kmR.

$$P + q = \boxed{\$\qquad}$$

N-31

The ratio of $\frac{180,000}{6,000}$ is $\boxed{\#\quad}$.

N-13

The lowest common denominator for $\frac{1}{6} + \frac{1}{12} + \frac{2}{3} = \boxed{\#\quad}$. The sum of these fractions is $\boxed{\#\quad}$.

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N-7

An addition problem that includes decimals is also easy if you remember to line up the problem so that the decimal points are lined up with each other. The sum of 4.2 and 6.3 is [#].

N-25

In physics, many division problems are written as a ratio or proportion. For instance, $\frac{10}{6}$ is the same as saying 10 divided by 6, and $\frac{3}{9}$ is the same as saying [#] divided by [#].

N-43

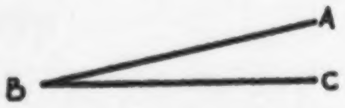
In general, when we know the area of a rectangle, and the length of the base, we can find the height. We could use the formula $A = bh$ by first changing the formula, by algebra, to $\frac{A}{b} = h$. Using this formula, if $A = 24$ and $b = 6$, $h =$ [#].

N-61

When we measure the length of something, we see how many inches long it is or how many feet long it is. A pencil, for example, is about six [ ] long and a log might be about ten [ ] long.

N-79

When two lines are not parallel, they form an angle with each other. Lines AB and BC form an [ ].



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n-84

smaller than

n-66

unit (of measure)

n-48

equal

n-30

2

n-12

$\frac{7}{12}$

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n-7

10.5

n-25

3

9

n-43

4

n-61

inches

feet

n-79

angle

A·I·R ©1960

N-84

Angles are measured in degrees. Figure A shows an angle of about 45 degrees and figure B shows an angle of about 80 degrees. Angle A is (larger than/smaller than) $\boxed{}$ angle B.

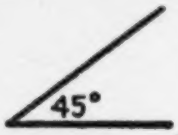

FIG. A

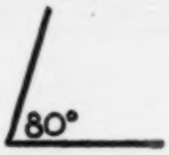

FIG. B

N-66

You must always indicate the $\boxed{*}$ when giving the answer to a problem.

N-48

As long as we do the same thing to both sides of a formula; add the same number, subtract the same number, multiply by the same number, or divide by the same number, one side will still $\boxed{}$ the other side.

N-30

When numbers are in the form of a proportion, we can cancel zeros to make division easier. For instance, if we have $\frac{100,000}{50,000}$ we can cancel an equal number of zeros from the top and bottom, $\frac{10\cancel{0},\cancel{000}}{5\cancel{0},\cancel{000}} = \frac{10}{5} = \boxed{\#}$.

N-12

We have to try larger and larger denominators until we find one that works. For instance, the lowest common denominator for $\frac{1}{4} + \frac{1}{3}$ is 12. To add, we write $\frac{3}{12} + \frac{4}{12} = \boxed{\#}$.

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㊴

N-8

To add 47.695 and 12.3, we would write:

$$\begin{array}{r} 47.695 \\ +\ 12.300 \\ \hline \boxed{\#\qquad} \end{array}$$

N-26

Sometimes, in physics, we make a proportion out of two numbers. For instance, to compare the diameter of one wheel with the diameter of another, we would make a $\boxed{\qquad\qquad}$ out of the two diameters. The answer is usually called an index or ratio.

N-44

Suppose we knew the area of a rectangle, and the length of the base, but not the height. We could also use the formula $A = bh$ by first changing the formula, by algebra, to $\frac{A}{b} = h$. If $A = 24$ and $b = 6$, $h = \boxed{\#\qquad}$.

N-62

Inches and feet are what we call units of measure. To describe the length of an object, we say it is so many units long, as nine inches or seven feet. Yards and miles are also $\boxed{\qquad\qquad}$ of length.

N-80

The angle formed by the lines in figure 1 is larger than the angle in figure 2. The angle in figure 3 is (larger/smaller) $\boxed{\qquad\qquad}$ than the angle in figure 2.

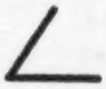
FIG. 1

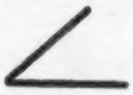
FIG. 2

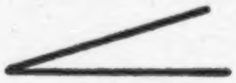
FIG. 3

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n-83

OMS
PQR

---

n-65

unit

---

n-47

22

---

n-29

proportion

9

$\frac{3}{20}$ or 1.5

---

n-11

$\frac{5}{6}$

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n-8

59.995

n-26

proportion

n-44

4

n-62

units

n-80

smaller

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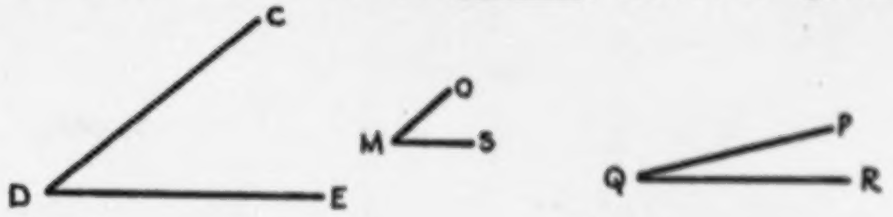
N-83

Angle CDE is the same size as angle $\boxed{\$\quad}$, but it is larger than angle $\boxed{\$\quad}$.



N-65

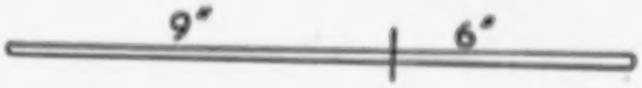
Whenever a physicist talks about a measurement, he always indicates the unit of measure. You do not know how long a piece of string is when someone says it is "5 long" because they did not tell you the $\boxed{}$ of measure they were using.

N-47

If A = 15, b = 3, and h = 5, the formula would read A = bh or 15 = 3 x 5. If we change the formula to read A + 7 = bh + 7, and read the numbers, we would have 15 + 7 = 3 x 5 + 7, or 22 = 15 + 7, or 22 = $\boxed{\#\quad}$.

N-29

To find the ratio of the length of the left part of this stick compared with the length of the right part, we would make the $\boxed{}$ $\frac{\boxed{\#}}{6}$. This gives a ratio of $\boxed{\#\quad}$.



N-11

In the problem $\frac{1}{2} + \frac{1}{3}$, 3 is not the lowest common denominator because 2 will not go into 3 evenly. When this happens, we should try multiplying the largest denominator in the problem by 2. This will give us $\frac{3}{6} + \frac{2}{6} = \boxed{\#\quad}$.

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N-9

To add fractions, we need to find the lowest common denominator; that is, each fraction must have the same denominator before we can add them. To add $\frac{1}{4} + \frac{1}{2}$, we change the $\frac{1}{2}$ to read $\frac{2}{4}$. Now we have $\frac{1}{4} + \frac{2}{4} =$ [#].

N-27

To find the ratio of boys to girls in a class, we would make a [ ] of the number of boys and number of girls. If there were 20 boys and 10 girls, the proportion would be $\frac{20}{10}$. If there were 30 boys and 5 girls, the proportion would be the fraction [#].

N-45

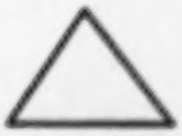
A formula is something like a balance like the one pictured here. The balance will be even only if we always do the same thing to both sides. If we add 2 ounces to the left, we have to add [#] ounces to the right.

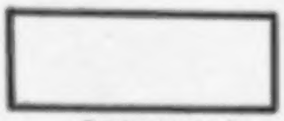
N-63

Sometimes different people use different [ ] of measure, depending on what they want to say. One person may say a stick is two feet long while another says it is [#] inches long.

N-81

A triangle has [#] angles, a rectangle has [#] angles.





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n-82

M

n-64

meter

yard

n-46

add it to the other side also

7

n-28

proportion

2

n-10

lowest common denominator

$\frac{3}{6}$ or $\frac{1}{2}$

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n-9

$\frac{3}{4}$

n-27

proportion

$\frac{30}{5}$

n-45

2

n-63

units

24

n-81

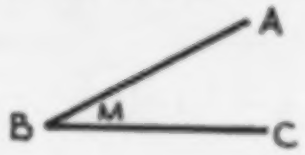
3

4

A·I·R ©1960

N-82

An angle is identified in either of two ways, by the lines that form the angle, or by a single letter in the angle. This angle could be called either angle ABC or angle $\boxed{\$\quad}$.



N-64

Most scientists do not use inches, feet, yards, and miles as units of length. They use a unit called a meter which is 39.37 inches. Their unit, the $\boxed{}$, is a little longer than the unit we use, called a $\boxed{}$.

N-46

In a formula, such as A = bh, we can always add a number to one side if we $\boxed{**}$. For instance, A + 7 = bh + $\boxed{\text{¢}\quad}$.

N-28

Once we have a proportion, to find a ratio or index, we divide the upper number (the numerator) by the lower number (the denominator). For instance, to find the ratio of boys to girls when there are 20 boys and 10 girls, we make the $\boxed{}$ $\frac{20}{10}$, and then divide, which gives us a ratio of $\boxed{\text{¢}\quad}$.

N-10

To find the lowest common denominator, it is easiest to start with the largest denominator and see if the other denominators will divide into it evenly. To add $\frac{1}{3} + \frac{1}{6}$, we can use 6 as the $\boxed{*}$ and write $\frac{2}{6} + \frac{1}{6} = \boxed{\text{¢}\quad}$.

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X

TURN BOOK AROUND AND CONTINUE HERE

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TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

③

PRECEDING PAGES MISSING - 122

UNIT ONE

STATIC ELECTRICITY AND ELECTRICAL CHARGES

Steps A-1 through A-142

④

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

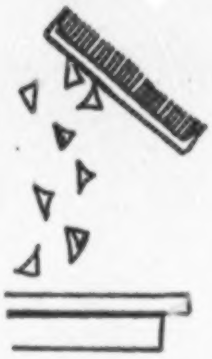
TURN BOOK AROUND AND CONTINUE HERE

UNIT ENDS HERE

⑤

A-1

A very important discovery in physics was the mutual attraction of objects due to static electricity. If we rub a hard rubber comb with a wool cloth and hold it over bits of tissue paper, the comb will attract the paper. This attraction illustrates ______ electricity.

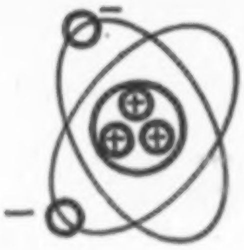


A-31

Two positive charges are "like charges" so they repel each other. A negative charge and a positive charge are ______*______ and they attract each other.

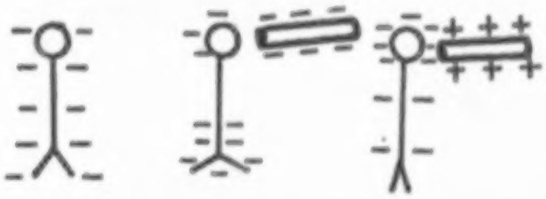
A-61

If an atom is positively charged it does not mean that the atom has no electrons. It means there are more ______ charges present than there are electrons.



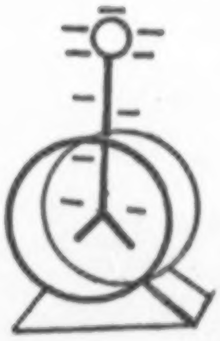
A-91

The distance between the gold leaves of an electroscope depends on the strength of the charge. A strong charge will cause the leaves to move ______ apart than a weak charge. If we start with a negatively charged electroscope, a negative rod brought near the knob will cause the leaves to move ______*______. If a positive rod is brought near the knob, the leaves will move ______*______.



A-121

If an electroscope is charged negatively, the leaves will move away from each other because ______**______ ______.



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a-120

conductors
insulators
semiconductors

a-90

electrons
not as such

a-60

equal
positive and negative charges
positive
negative

a-30

attract
repel
repel

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⑦

a-1

static

a-31

unlike charges

a-61

positive

a-91

farther
farther apart
closer together

a-121

they are both charged negatively and like charges repel.

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A-120

Substances are classified by their ability to conduct electric charge. The three types are called ☐, ☐ and ☐.

A-90

An electroscope has a negative charge. If we bring a charged object with a positive sign near the electroscope, the gold leaves will come together. This is because the negatively charged ☐ in the electroscope were attracted by the rod. The electrons in the leaves will tend to move up the stem to the knob. This will leave fewer electrons in the leaves of the electroscope. The leaves will still repel each other but (even more/not as much) ☐ as before.

A-60

If a neutral atom loses an electron it will no longer have an ☐ number of ☐ * . It will now have more ☐ charges than ☐ charges.

A-30

Look at the combination below and decide whether attraction or repulsion will take place.

+ charge and - charge will ☐ each other
- charge and - charge will ☐ each other
+ charge and + charge will ☐ each other

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A-2

At parties, you have probably seen someone rub balloons against a wool rug to make the balloons stick to the walls or ceiling. This is another example of * ______.

A-32

The general rule is that ______ charges attract and ______ charges repel.

A-62

If an atom is negatively charged, it does not mean that there are no positive charges. It does mean that there are more ______ present than positive charges.

A-92

An electroscope is a device for ** ______ and for ** ______.

A-122

Electrons themselves are always charged ______. Because they all have the same charge, electrons will always ______ each other.

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a-119

detect the presence of an electric charge
determine the sign of the charge

a-89

repel

a-59

positively
neutral

a-29

attract
repel
repel

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a-2

static electricity

a-32

unlike
like

a-62

electrons (or, negative charges)

a-92

detecting the presence of charge
determining the sign of the charge.

a-122

negatively
repel

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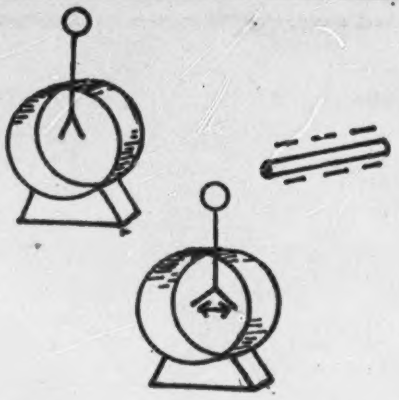
A-119

We can use an electroscope to tell us two things about an electric charge: we can
** ______ and
** ______.

A-89

An electroscope has been negatively charged. To find the sign of another charged object, we bring the object near the electroscope (but without touching it). If the object also has a negative charge, the gold leaves will move farther apart. The leaves will ______ each other even more.



A-59

If an atom has more positive charges than electrons, it is no longer neutral. It has become ______ charged. Only when charges are balanced in an atom is it ______.

A-29

A positive charge and a negative charge will ______ each other. Two negative charges will ______ each other. Two + charges will ______ each other.

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⑬

A-3

In ______ electricity, some objects will attract each other. A hard rubber comb rubbed against wool will ______ bits of tissue paper.

A-33

The general rule for attraction and repulsion is that ** ______ .

A-63

All atoms contain ______ which are positively charged. Around the ______ are negatively charged ______ .

A-93

A substance which will easily allow a charge to move through it is called a conductor. Copper wire is one substance that will easily allow a charge to move through it. Copper wire is a ______ of electric charge.

A-123

A conductor has many free ______ . Because they all have the same sign, they will all ** ______ .

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a-118

electroscope

a-88

apart

a-58

negatively

a-28

positive charge

(14)

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⑮

a-3

static
attract

a-33

like charges repel and unlike charges attract (or you could say, unlike charges attract and like charges repel).

a-63

nuclei
nuclei
electrons

a-93

conductor

a-123

electrons
repel each other

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A-118

An instrument used to detect the presence of a charge or the sign of a charged object is called an [   ].

A-88

When a negatively charged rod is brought near an electroscope that has already been negatively charged, the electrons in the rod will cause the electrons in the knob to move down the stem to the leaves. So the leaves will have even more negative charge. Therefore leaves will move even farther [   ].

A-58

When an atom has more electrons than positive charges, it is no longer neutral. It has become [   ] charged.

A-28

When we speak of the sign of a charge we refer to its being positive (+) or negative (-). An object with a negative charge will be attracted to an object with a [*   ].

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⑰

A-4

Still another example of static electricity can be seen when a piece of amber that has been rubbed with silk will ________ small objects.

A-34

Almost all matter we are familiar with is made up of molecules. Salt, for instance, is made up of many salt molecules. Water is made up of many water ________ .

A-64

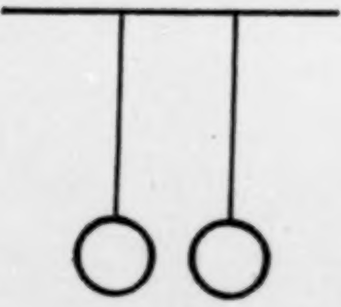
An atom with equal amounts of * ________ and * ________ is called a ________ atom.

A-94

As a general rule, metals such as copper are ________ of electric charge.

A-124

Pith balls are small, light weight, pieces of insulating material. They can be charged, but do not conduct charges. If we hang two pith balls from pieces of string, they will look like those in the figure. If we charge both pith balls negatively, they will ** ________ .



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a-117

negatively charged
positively charged

a-87

electrons
electrons
electrons
repelled

a-57

free
free
negative
negative

a-27

+
-

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a-4

attract

a-34

molecules

a-64

negative (positive) charge
positive (negative) charge
neutral

a-94

conductors

a-124

repel each other (or, move apart).

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A-117

Atoms gaining electrons become * ______. Atoms losing electrons become * ______.

A-87

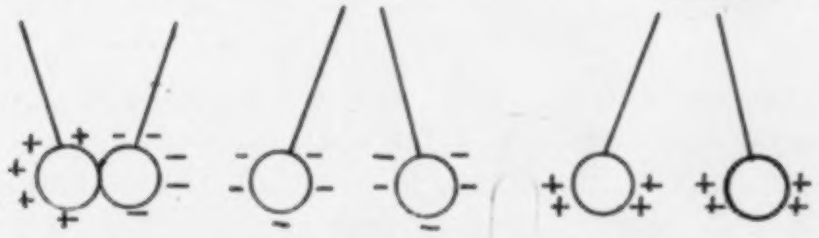
After an electroscope has received a negative charge, it has a surplus of negatively charged ______. A negatively charged rod also has a surplus of ______. If the rod is brought near the knob of the electroscope, the ______ in the knob will be ______ by those in the rod.

A-57

Only ______ electrons can move from one atom to another. When a ______ electron moves from one atom to another, the first atom loses a ______ charge. The second atom gains an electron and thus gains a ______ charge.

A-27

We use "+" to indicate positive and "-" to indicate negative. This is merely a convenient way of referring to electric charges. A - charge will be attracted to a $ ______ charge. A - charge will be repelled by a $ ______ charge.



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A-5

Static electricity can also cause objects to repel each other. When a comb rubbed through fur is brought near another comb rubbed through fur, the combs will not attract each other but will ☐ each other.

A-35

Molecules themselves consist of still smaller particules called atoms. Atoms combine and form different molecules. A salt molecule is made up of an atom of sodium and an atom of chlorine. A water molecule is made up of two atoms of hydrogen and one ☐ of oxygen.

A-65

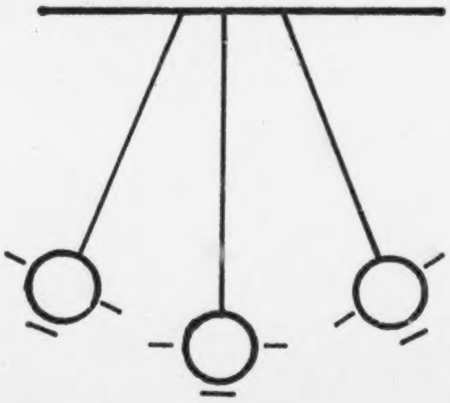
Some atoms have an affinity (attraction) for the free electrons of other atoms. Atoms with a strong electron affinity tend to take free electrons from atoms which have a weak electron affinity. When an atom takes free electrons from another atom we say the first atom has a strong ☐* and the second atom has a weak ☐*.

A-95

A copper wire will conduct electric charges. Copper wire is called a ☐. Other metals are also called ☐ because they ☐ electric charges.

A-125

If we hang three pith balls from pieces of string and charge all of them negatively, they will look like those in the figure. This is because they all have like charges and therefore ☐ each other.



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a-116

electron affinity

a-86

electrons
electrons

a-56

negative

a-26

negatively
negative

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㉓

a-5

repel

a-35

atom

a-65

electron affinity
electron affinity

a-95

conductor
conductors
conduct

a-125

repel

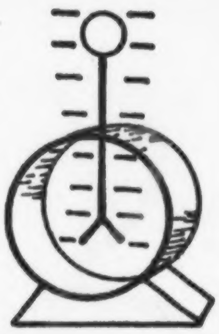
A·I·R ©1960

A-116

Some atoms will take electrons from other atoms because they have a stronger ☐ *.

A-86

When an object has a negative charge, this means it has a surplus of electrons. When an electroscope has a negative charge, the extra ☐ will be distributed over the knob, the stem, and the leaves. Although we can only see the leaves move apart, there are also extra ☐ in the stem and the knob.



A-56

Electrons are negatively charged. If an atom loses an electron it loses a ☐ charge.

A-26

Knowing that like charges repel each other and unlike charges attract, we would say that a positively charged object will be attracted to a ☐ charged object. Sometimes we talk about a "charge" as well as a "charged object". It is also true, then, that a positive charge will be attracted to a ☐ charge.

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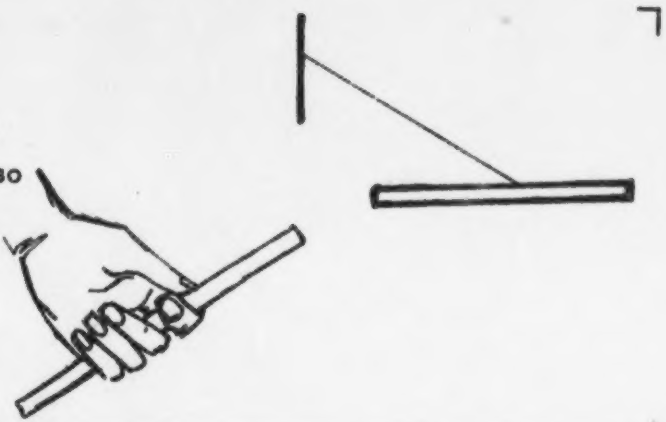
A-6

Knowing that two rubbed combs will repel each other, you would predict that two amber rods would also ________ each other after they have been rubbed.



A-36

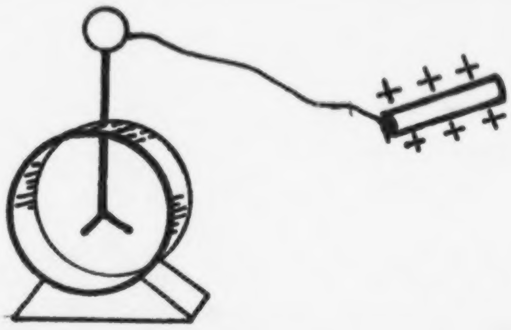
Most substances are made up of ________, which in turn are made up of ________.

A-66

An atom is neutral when it has an equal number of positive and negative charges. If a neutral atom gains electrons because of its strong * ________ the atom will no longer be neutral. It will then have more negatively charged ________ than it has * ________ in its nucleus.

A-96

If we attach a copper wire to the knob of an electroscope and touch the copper with a charged rod, the leaves of the electroscope will move apart. The charge has been ________ along the wire to the electroscope.



A-126

Let us suppose we have three negatively charged pith balls and then bring a negatively charged object near one of the end balls. The object will repel the end ball and cause it to move over. The end ball, in turn, will ________ the middle ball and cause it to * ________ also.

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a-115

positive (negative)
negative (positive)
neutral

a-85

negative
repel each other (or, move apart)

a-55

negatively

a-25

like

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㉗

a-6

repel

a-36

molecules
atoms

a-66

electron affinity
electrons
positive charges

a-96

conducted

a-126

repel
move over

A·I·R ©1960

A-115

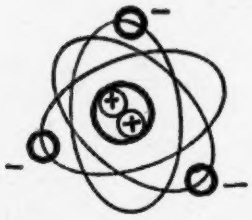
Atoms containing equal amounts of ________ and ________ charges are electrically ________.

A-85

To detect the sign of a charged object we first charge the electroscope with a known charge. We already know that a rubber rod rubbed against fur becomes negatively charged. This charged rod, when touched to the electroscope, will therefore give the electroscope a ________ charge. This will cause the gold leaves to * ________.

A-55

If an atom has more electrons than positive charges, it is a ________ charged atom.



A-25

Two combs which have both been rubbed with fur will repel each other. This shows that the two combs have (like/unlike) ________ charges.

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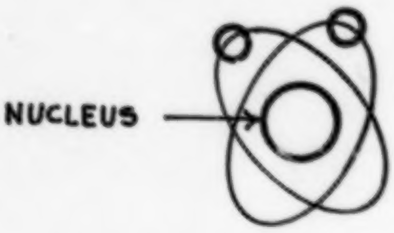
A-7

Static electricity causes some objects to come together; that is, to ________ each other. It causes other objects to move apart; that is, to ________ each other.

A-37

The modern theory of electricity is based on our knowledge of atoms. Every atom contains a center which is called the nucleus. The center of the atom; that is, the ________, has a positive charge.



A-67

When a neutral atom gains electrons from another atom, the atom gaining the electrons becomes negatively charged. This is because electrons have a * ________.

A-97

Some substances will not ordinarily conduct charges. We call these substances nonconductors or insulators. Ordinarily, paper will not conduct an electric charge. Paper is a nonconductor or ________.

A-127

Three negatively charged balls are shown in Fig. 1. Complete the second figure by drawing the third ball and an arrow to show how the three balls will look after a negatively charged object is brought near ball A.

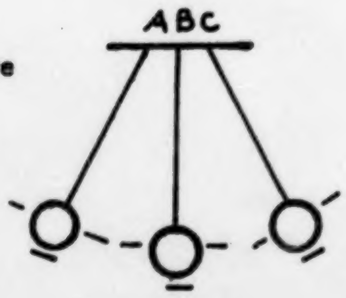


FIG. 1

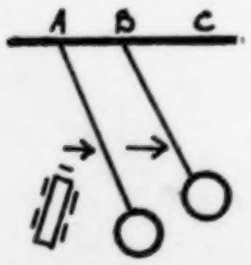


FIG. 2

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a-114

nucleus
positive
nucleus
electrons
negatively

a-84

electroscope
charge
sign
charge

a-54

positively

a-24

unlike

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㉛

a-7

attract
repel

a-37

nucleus

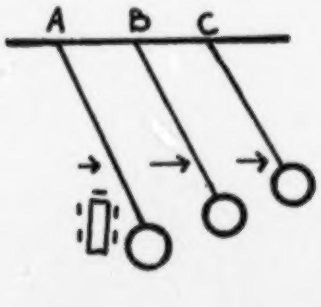
a-67

negative charge

a-97

insulator

a-127



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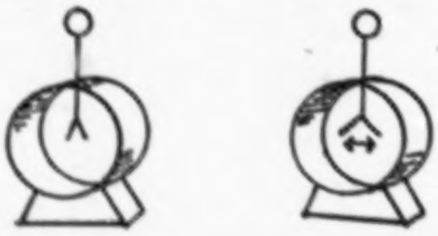
A-114

The center of an atom is called a ________. It has a ________ charge. Around this ________ are ________ which are ________ charged.

A-84

If we touch a charged amber rod to the knob of an electroscope, the gold leaves will move apart. The leaves are repelled by each other because they have both received a like charge. Using the ________ we have detected the presence of charge on the amber rod. We use an electroscope when we wish to detect the presence of a ________ or determine the ________ of a ________.



A-54

If an atom has more positive charges than negative charges, it is a ________ charged atom.

A-24

A rubber comb rubbed through fur will then attract the fur. From this we know that the comb and the fur have (like/unlike) ________ charges.

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A-8

Both attraction and repulsion are examples of * ______. Objects moving together is known as ______. Objects moving away from each other is known as ______.

A-38

The center of every atom is the ______. This part of the atom, the ______, has a ______ charge.

A-68

If an atom loses some of its electrons it is no longer neutral because it has more positive charges than negative charges. This atom is said to be ______ charged.

A-98

String is an insulator. If we attached string to an electroscope and touched a charged rod to the string, the gold leaves on the electroscope would not move. The charge was not ______ by the string.

A-128

Suppose we have a row of electrons and add one more electron at one end. The new electron will ______ the electron next to it and cause it to * ______. This electron will, in turn, ______ the electron next to it and cause the next one to * ______.

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END OF UNIT

a-113

repel
unlike charges attract

a-83

electroscope

a-53

positive

a-23

charged objects
attract

A·I·R ©1960

a-8

static electricity
attraction
repulsion

---

a-38

nucleus
nucleus
positive

---

a-68

positively

---

a-98

conducted

---

a-128

repel
move over
repel
move over

A·I·R ©1960

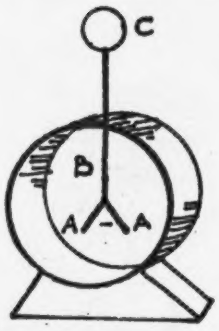
END OF UNIT

A-113

The general rule is that like charges ______ and * ______ ______.

A-83

One kind of electroscope consists of two thin pieces of gold leaf, or foil, hanging from a metal rod. On top of the rod is attached a metal ball or disc. In order to detect electric charges, or determine the sign of a charge, we may use an instrument such as the one pictured, called an ______.



A-53

Only the free electrons in an atom may move to another atom. The electrons which are not free remain around the nucleus. The nucleus keeps the same ______ charge it had before.

A-23

As a general rule, we say like charged objects will repel each other and unlike * ______ will ______ each other.

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A-9

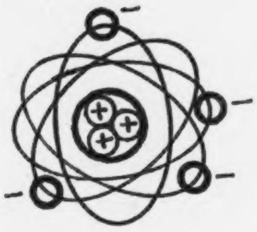
Physicists know that static electricity can cause either [   ] or [   ] between objects.

A-39

When we speak of more than one nucleus we use the plural form nuclei. We then say that atoms all have [   ] and these [   ] all contain positive charges.

A-69

The atom pictured below has [#] positive charges in the [   ] and [#] negative charges around it. Therefore, the atom has a [   ] charge.



A-99

A charge is conducted whenever electrons are free to move from one atom to another. Substances which are conductors contain atoms having [*].

A-129

If a negative charge is added to a long row of electrons, each electron will be [   ] by the one before it and will therefore [*].

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a-142

negative charge
positive charge

a-112

positive (negative)
negative (positive)
+ (-)
- (+)

a-82

electroscope
electroscope
positive (negative)
negative (positive)

a-52

free electrons

a-22

like

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a-9

attraction (repulsion)
repulsion (attraction)

a-39

nuclei
nuclei

a-69

3
nucleus
4
negative

a-99

free electrons

a-129

repelled
move over

A·I·R ©1960

A-142

Electrons flow away from a * ______ or toward a * ______.

A-112

There are two kinds of electric charges. One is called ______ and the other, ______. The symbols we use for these charges are $ ______ and $ ______.

A-82

We can detect the presence of charge on an object by using an ______. We can also use an ______ to tell whether an object has a ______ or ______ charge.

A-52

Not all the electrons in an atom are free to move from atom to atom. Only the * ______ can leave one atom and go to another.

A-22

Repulsion occurs when two objects have (like/unlike) ______ charges.

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A-10

When we rub a piece of amber on a silk cloth, the amber receives a charge of electricity. If we rub a comb through hair, the comb also receives a charge of electricity. Rubbing a balloon against a wool rug will give the balloon a ________ of electricity.

A-40

The center of every atom is the ________. The plural for this word is ________.

A-70

When amber is rubbed with fur, the amber will take free electrons from the fur because the amber has a stronger electron ________ than the fur. The amber (that is, the atoms making up the amber) then gains a ________ charge.

A-100

Only substances which contain ________ electrons are ________ of electricity. Nonconductors or ________ have no * ________ ________.

A-130

A conductor, such as copper wire, contains large numbers of free ________ ________. If we add a negative charge at one end, this will ________ all the electrons and cause them to * ________.

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a-141

movement of electrons along a conductor

a-111

static electricity

a-81

electroscope

a-51

electrons

a-21

unlike

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㊸

a-10

charge

a-40

nucleus
nuclei

a-70

affinity
negative

a-100

free
conductors
insulators
free electrons

a-130

electrons
repel
move over

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A-141

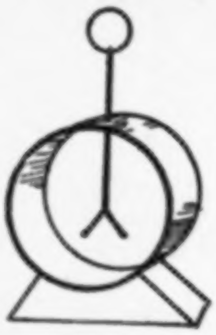
The flow of electrons means the ** .

A-111

When we refer to electric charges which are not moving or at rest, we are talking about * .

A-81

An electroscope is an instrument used to detect an electric charge and determine the sign of an electric charge. We can detect either a positive or a negative charge by using an .



A-51

Some types of atoms have electrons which are free to move from one atom to another. These electrons are called free .

A-21

Attraction occurs when objects have (like/unlike) charges.

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㊺

A-11

Static electricity is created when a comb is rubbed with wool. Rubbing the comb gives it a ________ of ________.

A-41

Atoms contain nuclei. The nuclei have a ________ charge.

A-71

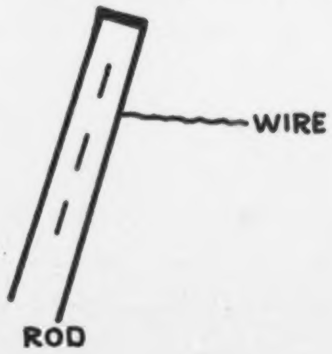
When the amber takes electrons from the fur, the fur loses some electrons. Therefore, the fur becomes ________ charged.

A-101

A substance which contains no free electrons and hence does not conduct charges is called an ________.

A-131

If a conductor, such as copper wire, is touched with a negatively charged rod, free electrons near the point of contact in the wire will be ________ by those in the rod and will therefore * ________.



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a-140

flow of electrons
negatively
positively

---

a-110

attraction
repulsion

---

a-80

electricity

---

a-50

nucleus
neutral

---

a-20

attract

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a-11

charge
electricity

a-41

positive

a-71

positively

a-101

insulator

a-131

repelled
move over

A·I·R ©1960

A-140

The movement of electrons along a conductor is called a * ______. Electrons will flow away from a ______ charged rod touching the conductor or toward a ______ charged rod touching the conductor.

A-110

In static electricity, we have objects which tend to come together because of the way they are charged and others which tend to move away from each other. The first is called ______ and the second, ______.

A-80

When electric charges are at rest we refer to it as static ______.

A-50

An atom with two positive charges in the ______ and two electrons around it is a ______ atom.

A-20

Two objects with a like charge will repel each other. Two objects with unlike charges will ______ each other.

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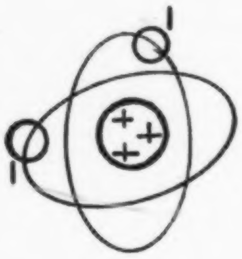
A-12

Static electricity means that an object has a ______ of ______ .

A-42

In the space around the nucleus of every atom, there are negative charges called electrons. Atoms are made up of positively charged nuclei and negatively charged ______ .



A-72

A rubber rod has a stronger electron affinity than fur. If a rubber rod is rubbed against fur, the rod will gain electrons and become * ______ .

A-102

Some rare substances are neither conductors nor insulators and are known as semiconductors. A substance which will not easily conduct a charge but is not a good insulator is called a ______ .

A-132

The movement of electrons along a conductor is called a flow of electrons. Electrons repelling each other, in turn, along a conductor is called a ______ of electrons.

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a-139

attracted
flow

a-109

conductor
insulator
semiconductor

a-79

negatively charged
positively charged
electron affinity

a-49

nucleus
electrons

a-19

charges

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(51)

a-12

charge
electricity

---

a-42

electrons

---

a-72

negatively charged

---

a-102

semiconductor

---

a-132

flow

A·I·R ©1960

A-139

If a positively charged rod is touched with a wire, electrons in the wire will be ________ by the positive charges on the rod. This movement of electrons is also an example of a ________ of electrons.

A-109

A substance which easily allows electrons to move is called a ________. A substance which least allows electrons to move is an ________. A substance which is in between these two kinds is a ________.

A-79

Atoms gaining electrons become * ________. Atoms losing electrons become * ________. Certain kinds of atoms which attract electrons from other atoms are said to have an * ________.

A-49

An atom is neutral when there are as many positive charges in the ________ as there are negatively charged ________ around it.

A-19

Two objects will repel each other when they both have the same or like charges. Two objects will attract each other when they have unlike ________.

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A-13

Static means "not moving" or "at rest". When electric charges are at rest we call this ______ electricity.

A-43

Around every nucleus there are negatively charged ______.

A-73

Two rubber rods which have been rubbed against fur will ______ each other. The two pieces of fur used will ______ each other.

A-103

Substances which have less free electrons than conductors but more than insulators are known as ______.

A-133

Conductors are the only substances having free electrons. Therefore, the movement of electrons, or the ______ of electrons only occurs along a ______.

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a-138

attract
together

---

a-108

semiconductors

---

a-78

affinity

---

a-48

neutral

---

a-18

negative

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a-13

static

a-43

electrons

a-73

repel
repel

a-103

semiconductors

a-133

flow
conductor

A·I·R ©1960

A-138

A positively charged object will ______ a negatively charged object. This means the two objects will move ______.

A-108

Some substances such as silicon and germanium are neither good conductors nor good insulators. They are called ______.

A-78

Atoms which attract electrons from other atoms are said to have an electron ______.

A-48

When an atom has an equal amount of positive and negative charges we call the atom a ______ atom.

A-18

There are two kinds of charges, one is called positive and the other ______.

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A-14

When an object is not moving, we say it is static. When electric charges are not moving we call this ________ electricity.

A-44

Atoms have centers which are called ________ and are ________ charged. Around the ________ of the atoms are ________ which are ________ charged.

A-74

When rubber is rubbed against fur, the fur loses electrons and becomes ________ charged. Therefore the negatively charged rod will ________ the fur.

A-104

Whether a substance is classed as a conductor, insulator, or semiconductor, depends on how easily charges of electricity move through it. An electric charge will move most easily through a substance having many * ________. These substances are called ________.

A-134

As each electron in a conductor is moved because of a negative charge at one end of the conductor, it forces the next electron to move. This is called a flow of electrons. Electrons only flow along a ________.

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a-137

flow

a-107

insulators

a-77

charges repel
unlike charges attract

a-47

negatively
electrons

a-17

charge
charge
positive charge

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a-14

static

a-44

nuclei
positively
nuclei
electrons
negatively

a-74

positively
attract

a-104

free electrons
conductors

a-134

conductor

A·I·R ©1960

A-137

When water flows through a pipe, it is because water added at one end will push the water in the pipe and force water near the other end out of the pipe. This movement of water is called a ☐ of water.

A-107

String, paper, glass, rubber, silk, are ☐.

A-77

The general rule in static electricity of attraction and repulsion is that like ☐ ** and ☐ **.

A-47

In a neutral atom the charges are balanced. If the nucleus has two positive charges, there will be two electrons associated with the atom. A neutral atom with ten positive charges in the nucleus will have ten ☐ charged ☐ associated with it.

A-17

There are two kinds of electric charges; one kind is positive and one is negative. When an object receives a ☐ of electricity, it will be either a negative ☐ or a ☐ *.

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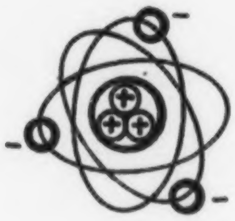
A-15

________ electricity refers to electric ________ which do not move.

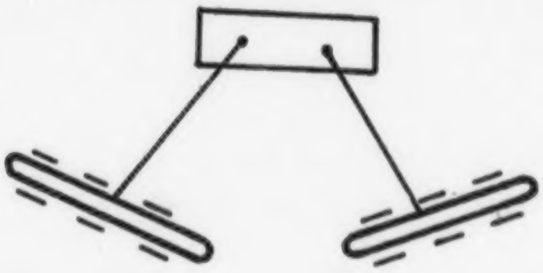
A-45

A neutral atom has an equal number of positive charges and negative charges. An atom with 3 positive charges and 3 negative charges is a ________ atom.



A-75

The repulsion between two charged rubber rods demonstrates the fact that like ** ________.



A-105

We classify a substance as a conductor, insulator or semiconductor by the degree of difficulty in causing electric charge to pass through it. List these three types of substances in the proper order from the easiest to the most difficult.

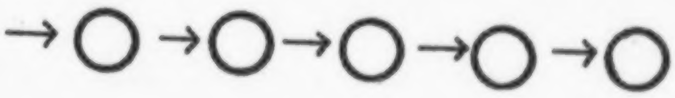
easiest

1. ________
2. ________
3. ________

most difficult

A-135

Picture a row of ping pong balls lined up on a table. A force exerted on the first ball moves it, it hits the second ball, the second ball hits the third, and so forth. This is similar to the movement of ________ as they ________ along a conductor.



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a-136

move apart
electrons

---

a-106

conductors

---

a-76

charges attract (each other)

---

a-46

neutral atom

---

a-16

attraction
repulsion
charge of electricity

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a-15

static
charges

a-45

neutral

a-75

charges repel each other

a-105

conductor
semiconductor
insulator

a-135

electrons
flow

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A-136

If a negatively charged rod is touched to a wire and the wire is connected to an electroscope, the leaves will * ______. This is due to an excess of negatively charged ______ in the leaves.

A-106

Copper, gold, iron and most other metals are ______.

A-76

The attraction of a charged rubber rod and fur demonstrates the fact that unlike ** ______.

A-46

An atom with two positive charges and two negative charges is a * ______.

A-16

Two examples of static electricity are the ______ and ______ of objects. Either can occur when an object is given a * ______.

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(65)
X

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UNIT TWO

COULOMB'S LAW, CONDUCTION, AND INDUCTION

Steps A-143 through A-266

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

UNIT ENDS HERE

A-143

Objects having like charges will ______ each other. Two negatively charged objects will ______ each other. Two positively charged objects will ______ each other.

A-169

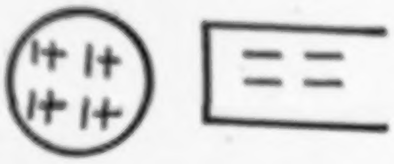
The law of electrostatic force, or ______ Law states that the force of attraction or repulsion between two charges is dependent on the product of the two charges and the ______ of the distance between them.

A-195

Coulomb's Law, the law of * ______ , states that the ______ force equals a constant times the product of the ** ______ divided by the * ______ .

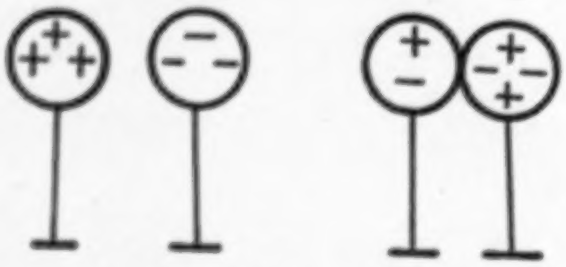
A-221

A pith ball, not covered with metallic foil, is an insulator. The electrons in it are ** ______ away from their atoms. However, a negative charge brought near the ball will cause electrons to be ______ within their atom; that is, they will move to the far side of their atoms.



A-247

Although after separation, the balls each have a different charge, one positive and one negative, the sum of the charges on the two balls is still the same. In other words, if they were brought back together again, they would again have a ______ charge.



a-246

induction
touching them

a-220

free electrons

a-194

The force would increase.
The force would decrease.

a-168

4
square
distance

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a-143

repel
repel
repel

---

a-169

Coulomb's
square

---

a-195

electrostatic force
electrostatic
(amount of) charges on the two objects
square of the distance (between the two objects)

---

a-221

not free to move
repelled

---

a-247

neutral

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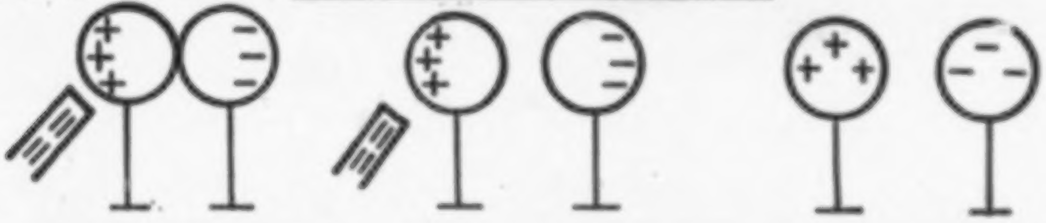
A-246

While the rod is near by, the balls are separated and then the charged rod is removed. The balls have been charged by a method called ______. This is the method of charging objects without * ______.



A-220

An uncharged pith ball covered with aluminum foil is an example of a neutral conductor. It is also possible for a neutral insulator to be attracted although an insulator does not have * ______ which can move from one side of the object to the other.

A-194

According to Coulomb's Law, what change would occur in the force between two charged objects if the distance between the two objects was left the same but the charge on each increased? ** ______. What would happen if the distance between the two charged objects was increased but charge on each of them remained the same? ** ______.

A-168

If objects are 2 meters apart, we square the number and obtain # ______; if objects are 3 meters apart, we ______ the number and obtain 9. In Coulomb's Law we always use the square of the ______ between the two objects.

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A-144

In an electroscope, the leaves move apart when both leaves receive ______ charges. The greater the charge, the farther the leaves will * ______.

A-170

According to Coulomb's Law, the greater the product of the two charges, the greater is the ______ of attraction or repulsion between them. Also, the more distance there is between the objects, the less will be the ______ of attraction or repulsion. We call this statement Coulomb's Law or the law of * ______.

A-196

Write Coulomb's Law in symbols $ ______. What does each symbol mean?

______

______

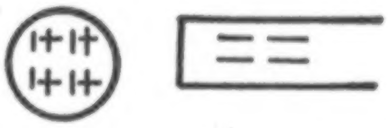
______

______

______

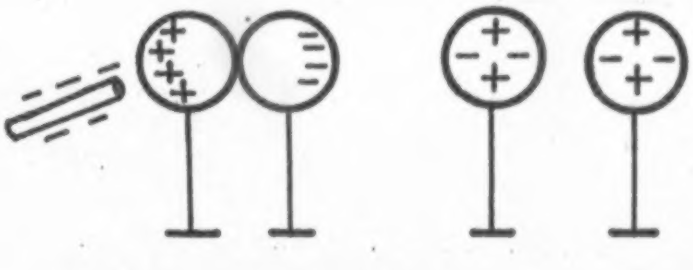
A-222

The electrons in an insulator merely shift from one side to the other within their atoms. This is called polarization. A charge brought near a neutral insulator will cause the electrons to shift their position within the atom in a process called ______.



A-248

It is important to remember that the balls must be separated before the charged rod is removed. If the rod is removed first, the electrons will go back to their original places, and if the balls are then separated, the balls will both have a ______ charge.



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a-245

more
negatively

---

a-219

move on to the rod
positive charge
repel each other
repelled
positively charged rod

---

a-193

greater

---

a-167

9

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a-144

like

move apart

a-170

force

force

electrostatic force

a-196

$F = k \frac{QQ'}{d^2}$

Q = charge on one object

Q'= charge on the other object

k = constant

F = force

d^2 = distance squared

a-222

polarization

a-248

neutral

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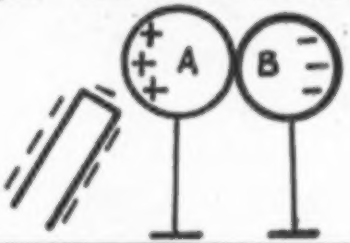
A-245

Because electrons are repelled toward the far side of ball B, the near side of A will have too few electrons and will be positively charged. Ball B will now have (more/less) ☐ electrons than it had before and will be ☐ charged.

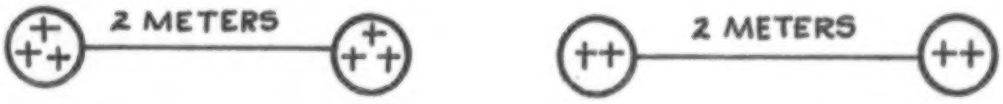


A-219

When a positively charged rod touches a neutral conductor, electrons from the object will ☐ ** . This leaves the conductor with a ☐ * . Since like charges ☐ * , the object is ☐ by the ☐ * .

A-193

Two charged objects, each with a charge of 3 coulombs and which are 2 meters apart, will have a (greater/smaller) ☐ force between them than two objects, each with a charge of 2 coulombs which are also 2 meters apart.



A-167

To compute the part of Coulomb's Law concerned with distance between two objects, we measure the distance between two objects in meters and square this number. If the objects are two meters apart, the number will be four. If the objects are three meters apart, the number will be ☐ # .

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A-145

Unlike charged objects ______ and like charged objects ______. The amount of "push or pull" causing the two objects to move apart or move together is the force of attraction or repulsion.

A-171

If we place a negative charge on each of two objects, they will tend to ______ each other. If we increase the amount of negative charge on either or both of the objects, the force of ______ between the objects will be ______.

A-197

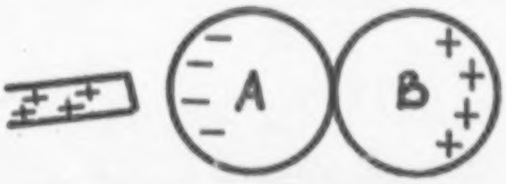
Coulomb's Law is very important. State the law in words. ** ______ ______.

A-223

When electrons in a conductor are repelled by a negative charge (or attracted by a positive charge), they will flow through the conductor. Electrons in an insulator can only move within their atoms, however, this is called ______.

A-249

If we used a positively charged rod, the electrons in ball B would move to ball A, leaving B with too few electrons and therefore ______ charged. Ball A will have a surplus of electrons and therefore will be * ______.



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a-244

repelled

a-218

repelled

a-192

newtons
coulombs
meters
constant

a-166

force

A·I·R ©1960

a-145

attract
repel

a-171

repel
repulsion
increased (or, greater)

a-197

The force of attraction or repulsion between two objects equals a constant times the product of the charges on two objects divided by the square of the distance between the objects.

a-223

polarization

a-249

positively
negatively charged

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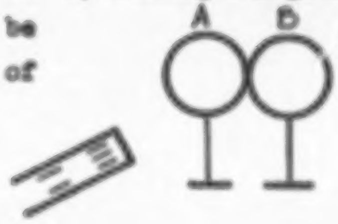
A-244

Charging by induction can be shown by placing two neutral metal balls on glass stands. The balls must be touching each other. By holding a negatively charged rod near ball A, the electrons in ball A and ball B will be ☐ toward the far side of B.



A-218

As the negatively charged rod touches the ball, electrons from the rod move on to the ball. The ball gains electrons, becomes negatively charged, and is ☐ by the rod.

A-192

In the formula $F = k\frac{QQ'}{d^2}$, F is force measured in ☐, Q and Q' are the charges measured in ☐, d is the distance measured in ☐ and k is a ☐.

A-166

The amount of force does not depend on whether the objects are positively or negatively charged. The signs of the charges indicate whether attraction or repulsion will tend to occur, but the amount of charge determines only the amount of electrostatic ☐.

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A-146

The amount of force of attraction or repulsion between two charges (that is, charged objects) can be determined by means of the law of electrostatic force formulated by Charles Coulomb. The names, Coulomb's Law and law of *__________ mean the same.

A-172

If we place a positive charge on each of two objects, they will tend to __________ each other. If we move the objects closer together, the force of __________ will be __________.

A-198

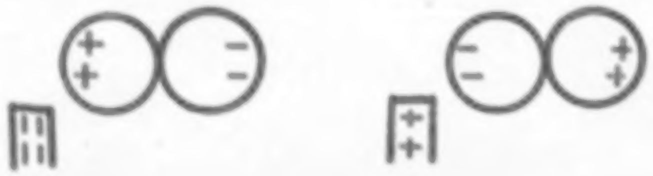
An atom having equal amounts of positive and negative charge is a neutral atom, but an atom having more electrons than positive charges is a *__________ atom. An atom having more positive charges than it has electrons is a *__________ atom.

A-224

When a negative rod is brought near a neutral insulator, such as a pith ball, __________ within the atoms will occur. The positive charges within each atom will be closer to the rod than the __________ and therefore the ball will be __________ to the rod.

A-250

Regardless of the sign of the charge on the rod, the object closer to the rod has the opposite sign from the rod and the object farther from the rod has the same sign. This is because like *__________ and unlike *__________.



a-243

positive and negative charges
conductors

a-217

negative
positive

a-191

force
distance
coulomb (or, unit)

a-165

increase
charge

⑱

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⑬

a-146

electrostatic force

---

a-172

repel
repulsion
increased (or, greater)

---

a-198

negatively charged
positively charged

---

a-224

polarization
electrons (or, negative charges)
attracted

---

a-250

charges repel
charges attract

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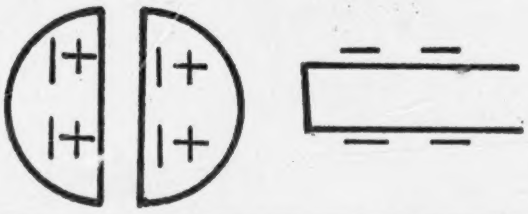
A-243

If a negative rod is brought near a pith ball, and the ball is cut in half, each half would still be neutral when the rod was removed because each half would still have the same number of ☐ * .

Only ☐ can be charged by induction.



A-217

When a negatively charged rod is brought near a neutral object, the object still is neutral but the side away from the rod is ☐ and the side near the rod is ☐ . Total amount of charge is still the same.

A-191

Charge is measured in units called coulombs. The greater the amount of charge on the two objects the greater is the ☐ of attraction or repulsion between them providing the ☐ between them is not changed. If two objects each have two coulombs of charge, the force between them will be increased if we add another ☐ of charge to either one of them.

A-165

According to Coulomb's Law, the amount of electrostatic force between two objects will ☐ if the amount of ☐ on either or both of the objects is increased, providing the distance between them is not changed.

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A-147

Coulomb's Law or the law of ____ force is a statement of the ____ of attraction or repulsion between two charged objects.

A-173

We can increase the amount of force between two charged objects by increasing the * ____ on either or both of the objects, or by decreasing the ____ between the objects.

A-199

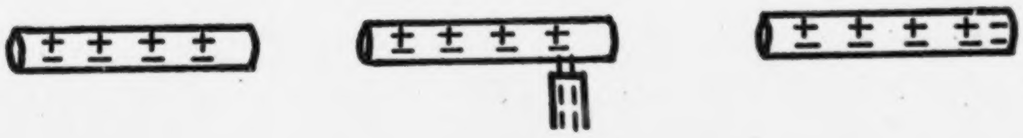
A neutral object is attracted toward an object which is either positively or negatively charged. By neutral object we mean one which has an equal amount of * ____ .

A-225

Objects having equal amounts of positive and negative charge are called ____ objects. When a negative rod is brought near a neutral insulator, attraction will tend to occur because ** ____ , and the positive charges will be nearer to the rod than the negative charges. Since the distance between ____ charges is now less than the distance between ____, the force of attraction will be greater than the force of repulsion.

A-251

An object which does not allow the movement of electrons is an ____ .
If a negatively charged rod is touched to a glass tube, the electrons from the rod that move onto the glass will stay at the point of contact.



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a-242

polarization
cannot

a-216

move to the side of the object nearest the rod
negatively
positively

a-190

1
repel

a-164

8
increased (or, doubled)

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a-147

electrostatic
force

a-173

amount of charge
distance

a-199

positive and negative charge

a-225

neutral
electrons will be repelled to the side of their atoms away from the rod
unlike
like

a-251

insulator

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A-242

Although an insulator will be attracted toward a charged rod without being touched, because ______ within each atom occurred, the insulator (can/cannot) ______ be charged by induction.

A-216

When a positively charged rod is brought near a neutral conductor, electrons in the conductor will ** ______. This causes the object to be attracted to the rod. This force of attraction is stronger than the force of repulsion because the ______ charged region of the object is nearer to the rod than the ______ charged region.

A-190

The figure showing the greater amount of force between objects is Fig. # ______. The plus signs indicate each object has one unit of positive charge on it. Thus we know that in each figure the objects will tend to ______ each other.

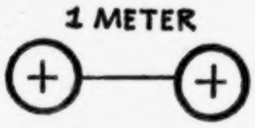

FIG. 1

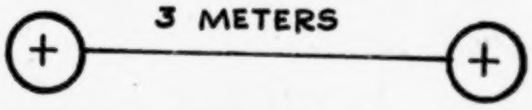

FIG. 2

A-164

Suppose we have two objects which each have two units of charge on them. Then QQ' would be 2 X 2 or 4. If we double the charge on the first object, QQ' would now be 4 X 2 or # ______. If the distance between them is not changed, the force between the two objects has been ______.

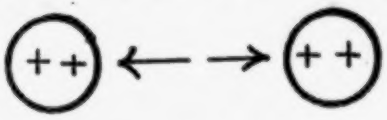

FIG. 1

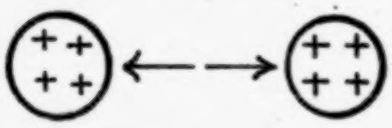

FIG. 2

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(89)

A-148

We can determine the force of attraction between two objects using Coulomb's Law; that is, the law of electrostatic ________. We can also determine the * ________ between two objects using * ________, the law of * ________.

A-174

The amount of charge on one object is indicated by the symbol Q, and the amount of charge on the other object is indicated by the symbol $ ____. The product of the ________ is written as QQ'.

A-200

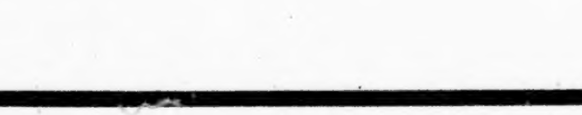
Objects made of material having free electrons will conduct charges and are called ________. Most metals are ________ of charges.

A-226

A negatively charged object will ________ a neutral object. A positively charged object will also ________ a neutral object. As a general statement, charged objects will always tend to ________ neutral objects.

A-252

If we were to break the glass in half, only the piece that was touched would have extra electrons. Piece A would have a ________ charge. Piece B would have a ________ charge.



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END OF UNIT

a-241

attracted to

a-215

attracted

a-189

decreases
less
meter

a-163

increases
amount of charge

A·I·R ©1960

91

a-148

force
force of repulsion
Coulomb's Law
electrostatic force

---

a-174

Q'
charges

---

a-200

conductors
conductors

---

a-226

attract
attract
attract

---

a-252

neutral
negative

A·I·R ©1960

END OF UNIT

A-241

When a charged rod is brought near a neutral insulator, polarization within each atom occurs. Because of the way the electrons shift within their atoms, the insulator will be *__________ the rod.

A-215

When a negatively charged rod is brought near a neutral object, the side nearest the negative rod becomes positively charged because the electrons are repelled to the far side. Because the distance between the rod and the negative region is greater than the distance between the rod and the positive region, the neutral object is __________ to the rod.

A-189

According to Coulomb's Law, increasing the distance between two objects __________ the force between them. If two objects have both been charged, there will be (more/less) __________ force between them if they are placed two meters apart than if they were placed one __________ apart.

A-163

One thing that Coulomb's Law tells us is that as the amount of charge on the objects increases, the electrostatic force between them __________ providing the distance between them is not changed. To compute this part of the law we multiply the amount of charge on one object by the *__________ on the other object.

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A-149

Like charges repel each other; unlike charges attract each other. The force of attraction or repulsion between two objects can be determined by using ________ Law, also called the law of electrostatic ________.

A-175

The distance between two objects is indicated by the symbol "d". The square of the ________ between them is indicated by the symbol "d^2". To calculate the amount of force between two objects, we divide the product of the ________ by the square of the ________ between them.

A-201

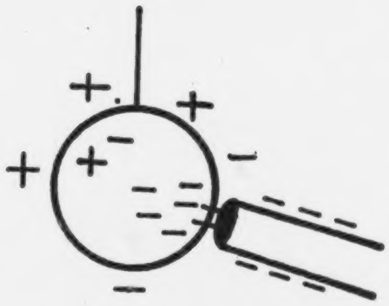
A ball made out of aluminum has free electrons. It will therefore ________ charges.

A-227

Conductors have free electrons which can move from one place to another. When a negative charge is brought near a neutral conductor, the ** ________ ________. This will leave the near side ________ charged.

A-253

An aluminum ball is a ________.
If a negatively charged rod touches the ball,
electrons from the rod would move onto the ball.



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a-266

$$F = k \frac{QQ'}{d^2}$$

a-240

polarization
positive and negative charges

a-214

move on to the neutral object
repulsion

a-188

newtons
meters
square

a-162

amount of charge
multiplying the amount of charge on the first object by the amount of charge on the second object (or multiplying, Q times Q')

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a-149

Coulomb's
force

a-175

distance
charges
distance

a-201

conduct

a-227

electrons move to the far side of the conductor
positively

a-253

conductor

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A-266

Using symbols, write Coulomb's Law. Remember a constant is in the formula.

F = [$].

A-240

An insulator cannot be charged by induction. In an insulator, the electrons will only shift within their atoms. This is called [ ]. If we were to cut the insulator in half, each half would still have an equal number of [*].

A-214

Attraction occurs when the rod is brought near the neutral object. When the rod touches the object, electrons from the rod [**]. Since they now have like charges, there will be a force of [ ] between the rod and the object.

A-188

$F = k\frac{QQ'}{d^2}$. Using the formula for Coulomb's Law, we can calculate the force of attraction or repulsion between two objects in units called [ ]. Distance is measured in meters, so to find d^2, we measure the distance between objects in [ ] and [ ] this number.

A-162

We use the symbol Q to stand for the amount of charge on the first object, and we use the symbol Q' (say, Q prime) to indicate the [*] on the second object. The product of the charges, QQ', is found by [**].

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A-150

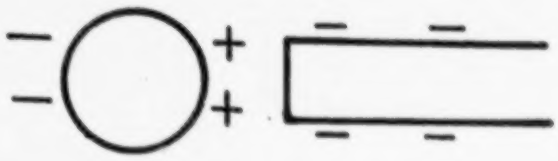
The amount of "push" causing objects to be repelled is called the force of repulsion. The amount of "pull" causing objects to be attracted is called the ______ of attraction. When physicists speak of a "push" or a "pull" they always use the word ______.

A-176

A constant in a formula is a number which never changes. The symbol "k" in a formula usually indicates a ______.

A-202

If a negatively charged rod is brought near an aluminum ball the electrons in the ball will be repelled toward the far side of the ball, leaving the near side with a positive charge. The electrons were repelled because the rod has a * ______ and electrons will be repelled by a * ______.



A-228

When a negative rod is brought near a neutral conductor, attraction occurs. How is part of Coulomb's Law demonstrated by the attraction of the neutral conductor? ** ______.

A-254

When the electrons from the rod move onto the ball, they move all over the ball, giving it a ______ charge.

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a-265

amount
distance
product of the amount of charge on one object times the amount of charge on the other object.

a-239

polarization

a-213

repel

a-187

$F = k \frac{QQ'}{d^2}$

a-161

distance

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a-150

force
force

a-176

constant

a-202

negative charge
negative charge (or, negatively charged rod)

a-228

The force of attraction or repulsion is greater for charges near each other than for charges farther apart.

a-254

negative

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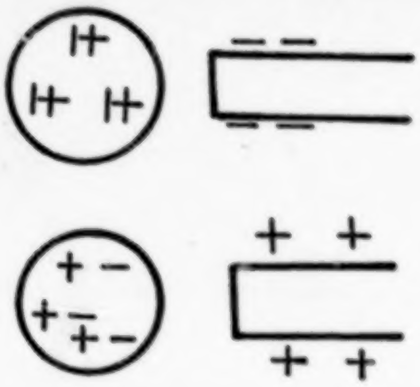
A-265

The electrostatic force between two objects depends on the ______ of the charge on each object and on the square of the ______ between the objects. In symbols, the formula is $F = k\frac{QQ'}{d^2}$. The part, QQ' is the ** ______.

A-239

When a charged rod is brought near an object made of insulating material, the electrons in the atom will shift position. This is called ______.



A-213

The ball is now negatively charged. Since both the ball and the rod are negatively charged they will now ______ each other.

A-187

Force of attraction or repulsion equals a constant times the product of the charges divided by the square of the distance between the objects. Write the equation for Coulomb's Law: F = $ ______.

A-161

To compute the force of attraction or repulsion between two objects we first multiply the amount of charge on each of the two objects. Then we find the square of the ______ between the objects.

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A-151

The law of ______ force, or ______ Law, is used to determine the ______ of attraction or repulsion between two charged objects.

A-177

A constant in a particular formula is always the same for that formula. A constant means a number used in a formula which never ______.

A-203

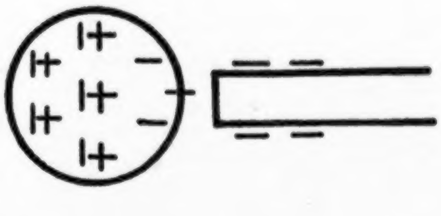
A pith ball is a small light ball often made from the material in the center of a corn cob. It is neither a conductor nor a semiconductor. It is an ______. If we wrap aluminum foil around the pith ball, the aluminum will act as a ______. This means that although the electrons in the pith ball are not free to move, the electrons in the aluminum foil are * ______.

A-229

When a negatively charged rod touches a neutral conductor, repulsion will tend to occur because ** ______.

A-255

If a neutral insulator is touched with a negative rod, the area that was touched would be given excess ______ and therefore have a * ______. The other parts of the ball would still be neutral.



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a-264

increased
increased

---

a-238

induction
conduction

---

a-212

negative charge

---

a-186

force of attraction or repulsion
a constant
the amount of charge on one object
the amount of charge on the other object
the distance between the two objects.

---

a-160

charges
distance

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a-151

electrostatic
Coulomb's
force

a-177

charges

a-203

insulator
conductor
free to move

a-229

electrons from the rod move on to the conductor giving the conductor a like charge, and like charges repel each other.

a-255

electrons
negative charge

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A-264

The force of attraction or repulsion between two objects increases as the product of the two charges is [ ] and decreases as the distance between them is [ ].

A-238

When a conductor is charged without being touched, by [ ], no charges are added to the conductor from the charged rod. The electrons in the conductor redistribute themselves. When an object is charged by touching it, by [ ], some charges are added to it.

A-212

As soon as a negatively charged rod touches the neutral ball, electrons from the rod will move on the ball. The ball will have gained electrons and will therefore no longer be neutral but will have a [*].

A-186

In Coulomb's Law, $F = k\frac{QQ'}{d^2}$, the symbol:

F stands for [*]
k stands for [*]
Q stands for [*]
Q' stands for [*]
d stands for [*].

A-160

Coulomb's Law states that the force of attraction or repulsion can be computed knowing the product of the [ ] on each object and the square of the [ ] between them.

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A-152

Two negatively charged objects will tend to repel each other. If the amount of negative charge on each object was doubled, the objects would tend to repel each other with more force because the amount of charge is greater. The amount of ______ on the two objects affects the force of repulsion or attraction.

A-178

Coulomb's Law uses a constant. We abbreviate it k. In Coulomb's Law, k equals 9×10^9. This is a very large number. Written out it would be 9 followed by 9 zeros (9,000,000,000). Any time we compute electrostatic force using Coulomb's Law, we use the number # ______ for k.

A-204

When a pith ball wrapped with aluminum has an equal amount of positive and negative charges, it is electrically ______.

A-230

Although there are no free electrons in an ______, it is possible for it to be attracted by a charged rod.

A-256

After being touched with a negative rod, the side of an insulator nearest the rod now will have a ______ charge because of the excess ______ it gained. The rod will then ______ by the insulator.

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a-263

electrostatic force
force
charges
distance

---

a-237

negative
negative
touch

---

a-211

neutral
attracted toward

---

a-185

increase
increase

---

a-159

less

A·I·R ©1960

107

a-152

charge

a-178

9×10^9 (or, 9,000,000,000)

a-204

neutral

a-230

insulator

a-256

negative
electrons
repelled

A·I·R ©1960

A-263

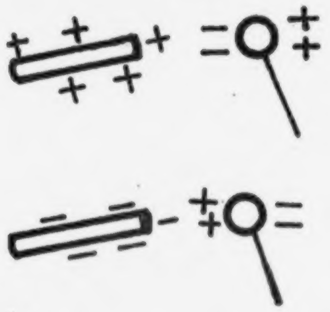
Coulomb's Law, as you remember, is also called the law of [*]. It states that the [ ] of attraction or repulsion between two objects is computed by multiplying a constant times the product of the [ ] divided by the square of the [ ] between the object.

A-237

If an aluminum covered pith ball was touched with a negative rod, electrons from the rod would move on to the ball giving the ball a [ ] charge. The ball was given a [ ] charge by allowing electrons to flow on to it. This is called charging by conduction. When we charge by conduction, the charged rod must [ ] the object.

A-211

When a charged rod is brought near a neutral object, the neutral object does not gain charge, it remains [ ]. However, many electrons move toward or away from the charged rod because of repulsion or attraction. Because differently charged regions are set up, the neutral object will always be [*] a charged object, whether it is charged positively or negatively.



A-185

Coulomb's Law states that increasing the charge on either or both of a pair of objects will [ ] the force of attraction or repulsion between them, and decreasing the distance will also [ ] the force.

A-159

Coulomb's Law also states that the greater the distance between two objects, the [ ] will be the force of attraction or repulsion so long as the product of charges is constant. Mathematically, the amount of force changes with respect to the square of the distance.

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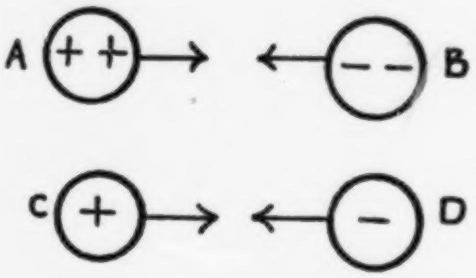
A-153

In this figure, objects A and B will ________ each other. Objects C and D will also ________ each other, but the strength of the ________ of attraction will be greater for objects $ ____ and $ ____ than for objects $ ____ and $ ____.

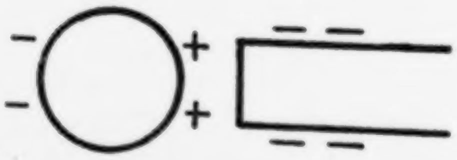


A-179

When we write a formula using a constant, we mean that the value is the same for the constant no matter how many times we use the formula. In Coulomb's Law, we know that the value of QQ' depends on the ________ on the objects, and the value for d^2 depends on the ________ between the objects, but the same number is always used for $ ____.

A-205

When a negatively charged rod is brought near a neutral pith ball, the electrons in the aluminum foil are repelled toward the far side of the ball, leaving the near side with a positive charge. The electrons were repelled because the rod has a * ________ ________ and * ________ repel each other.



A-231

When a charge is brought near a neutral insulator the electrons in the insulator shift position within their atoms. This is called ________.

A-257

When objects are charged without being touched, this is called charging by ________. When objects are charged by touching them with a charged object, this is called charging by ________.

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a-262

would not be

Because although the atoms were polarized when the rod was near the insulator, both halves still have an equal number of positive and negative charges.

a-236

induction

a charged rod is brought near a neutral conductor

charged rod

a-210

greater than the force of repulsion

attracted

a-184

decrease

newtons

increase the force of attraction or repulsion (between them)

a-158

increases

amount of charge

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a-153

attract
attract
force
A (and) B
C (and) D

a-179

charges
distance
k

a-205

negative charge
like charges

a-231

polarization

a-257

induction
conduction

A·I·R ©1960

A-262

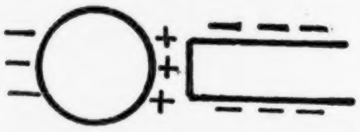
A negative rod is brought near a neutral insulator. If the insulator were cut in half, and then the rod removed, the halves (would be/would not be) * charged. Why? ** .

A-236

An object which has become charged without being touched has been charged by . Two steps are involved. First, ** and then the object is divided before the * is removed.

A-210

Since the distance between the rod and the positive region of the ball is less than that between the rod and the negative region of the ball, the force of attraction will be ** and the ball will be to the rod.



A-184

Increasing the distance between two charged objects will the force between them as measured in units called . Decreasing the distance between the two objects will ** .

A-158

Coulomb's Law states that as the amount of charge on the objects is increased, the force of attraction or repulsion (increases/decreases) so long as the distance between them is not changed. Mathematically, the amount of force is related to the product of the amount of charge on the two objects. To find the product of the charges, we multiply the amount of charge on one object by the * on the other.

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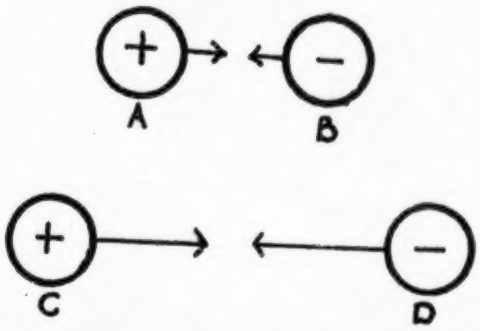
A-154

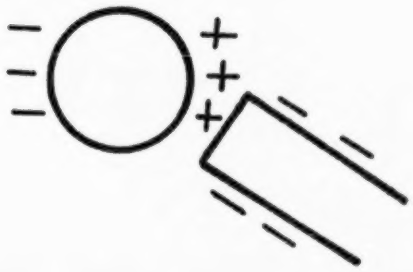


In this diagram, the force of attraction will be greater for A and B than for C and D because there is less distance between A and B than between C and D. Changing the distance between two charged objects will change the ________ of attraction or repulsion.

A-180

The equation for Coulomb's Law, the law of * ________, is written $F = k\frac{QQ'}{d^2}$. In this formula, Q and Q' are the amounts of charge on the two objects, d is the ________ between them, and k is a ________.

A-206



The figure shows the aluminum covered pith ball after the negatively charged rod has been brought near it. The ________ in the ball have been repelled by the rod. The side of the ball away from the rod will therefore have a ________ charge and the side near the rod will have a ________ charge.

A-232

If a positively charged rod is brought near a neutral insulator, attraction will occur. In this case, instead of electrons moving to the far side of each atom, ** ________.

A-258

The two steps involved in charging by induction are ** ________. To charge by conduction we ** ________.

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a-261

Electrons are attracted by the positive rod, making the far side of the conductor positive and the near side negative.

positive
negative

a-235

negative
positive
induction

a-209

less

a-183

increase
newtons

$F = k \frac{QQ'}{d^2}$

a-157

Coulomb's
charge
distance

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a-154

force

a-180

electrostatic force
distance
constant

a-206

electrons
negative
positive

a-232

they move to the near side (of each atom)

a-258

first, a charged rod is brought near a neutral object and then, the object is divided (or, cut in half) before the charged rod is removed.

touch the object with a charged rod.

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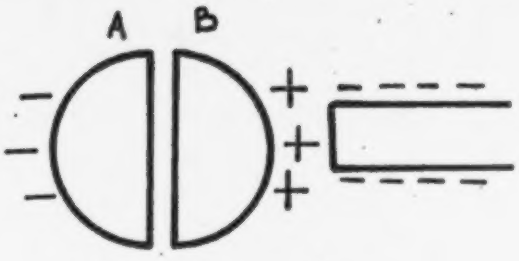
A-261

Describe what happens when a positive rod is brought near a conductor. ** . If the conductor were to be cut in half, the far side would be and the near side would be .

A-235

If an aluminum ball were cut in half after a negative charge were brought near it, half A would have a charge, half B would have a charge. The halves were charged by .



A-209

According to Coulomb's Law, the greater the distance between charged objects the (greater/less) will be the force of attraction or repulsion.

A-183

Physicists use the formula for Coulomb's Law to calculate the force of attraction or repulsion in units called newtons. Increasing the amount of charge on either (or both) objects will the force between them. The force of attraction or repulsion, measured in , is equal to: F = $.

A-157

The law of electrostatic force or Law states that the amount of attraction or repulsion between two objects depends on the amount of on the objects and the between them.

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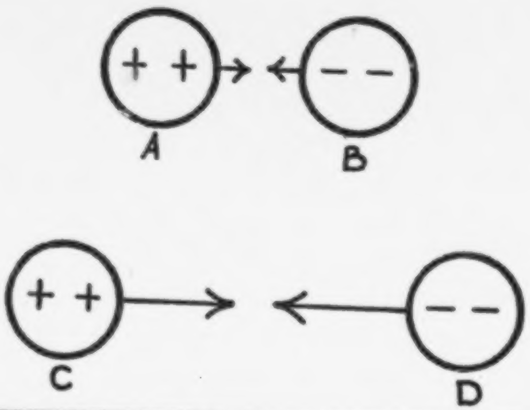
A-155

The ____ of attraction will be greater between objects $ ____ and $ ____ than between objects $ ____ and $ ____ because the ____ between the objects in each pair is different although the amount of charge is the same.

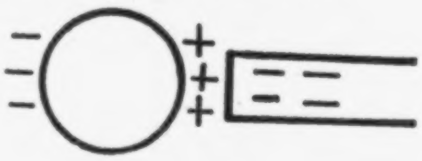


A-181

Coulomb's Law states the force of attraction or repulsion (F) is equal to a constant (k) times the product of the amount of charge on the two objects (QQ') divided by the distance between them squared (d^2). Write the formula: F = $ ____.

A-207

Coulomb's Law states that the greater the distance between two charges, the smaller the force of attraction or repulsion. The region of positive charge on the ball is nearer the rod than the region of negative charge. One side is attracted to the rod and the other side is ____. Since the positive region is nearer the rod, the force of ____ will be stronger than the force of ____, and the ball will tend to move toward the * ____.



A-233

Induction is the method of charging a conductor without touching it. If a negative rod is brought near an aluminum ball, the electrons will move to the far side of the ball. Bringing a charge near a neutral conductor to get one side positively charged and the other side negatively charged is the first step in charging the object by ____.

A-259

What happens when a positively charged rod is brought near a neutral conductor? ** ____. What happens when a positively charged rod is brought near a neutral insulator? ** ____.

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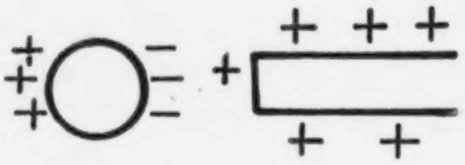
a-260

A negative rod is touched to the conductor, and thus electrons are added to conductor, and they become distributed over the conductor.

---

a-234

induction



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a-208

attracted to
attraction
positively
negatively

---

a-182

force
distance
constant

---

a-156

charge
distance

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⑪⑨

a-155

force

A (and) B

C (and) D

distance

---

a-181

$F = k \frac{QQ'}{d^2}$

---

a-207

repelled

attraction

repulsion

(negatively) charged rod

---

a-233

induction

---

a-259

The electrons move to the side nearest the charged rod, leaving the far side positive and the near side negative.

Polarization occurs, the electrons shift within the atom, moving toward the positively charged rod.

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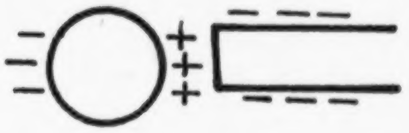
A-260

Describe how a conductor is negatively charged by conduction. ** ____.

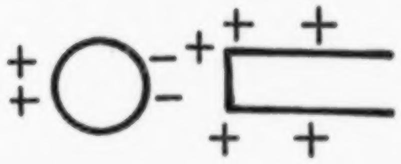
A-234

The drawing illustrates the first step in charging by ______________. The figure shows an aluminum ball when a negative rod has been brought near it. Draw another figure to show how the charges on an aluminum ball would be arranged if a positively charged rod were brought near it.



A-208

If a positively charged rod is brought near a neutral conductor, electrons in the object will be * ______________ the side nearest the charged rod. There will then be a force of ______________ between the object and the rod because the ______________ charged region on the object is farther from the rod than the ______________ charged region.



A-182

In the equation $F = k\frac{QQ'}{d^2}$, the symbol F stands for the ______________ of attraction or repulsion, Q and Q' stand for the amount of charge on the two objects, d^2 stands for the square of the ______________ between the objects, and k is the ______________.

A-156

Coulomb's Law states that the greater the amount of ______________ on the two objects, the greater the force of attraction or repulsion; and the greater the ______________ between two charged objects, the smaller will be the force of attraction or repulsion.

A·I·R ©1960

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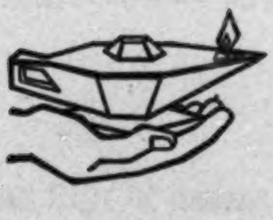
UNIT THREE

DISTRIBUTION OF CHARGE AND FLOW OF CURRENT

Steps A-267 through A-370



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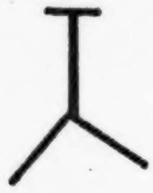
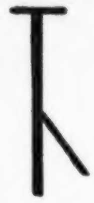
UNIT ENDS HERE

A-267

The electrometer (say, e-lek-troḿ-eter) is a special kind of electroscope in which one gold leaf is fastened in place so that only one gold leaf is free to move. An electrometer, just as an electroscope, will detect the presence of ☐.



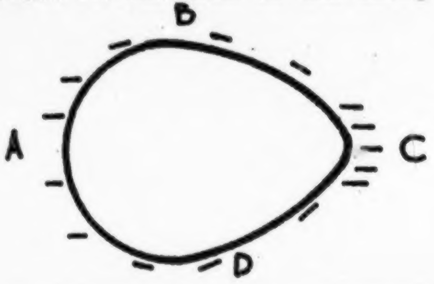
ELECTROSCOPE



ELECTROMETER

A-289

On an egg-shaped surface, the charge will be greatest in the area of the sharpest curve (C) and least where there is the least amount of curve (B & D). The sharper the curve, the greater is the ☐ ** .

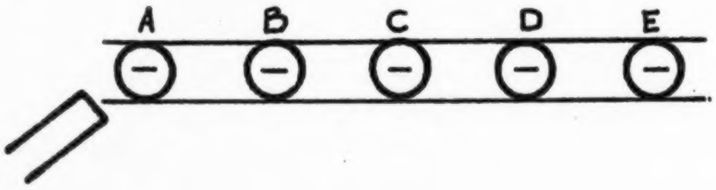


A-311

A sharply pointed, negatively charged object forces some electrons into the ☐. This is called an electrical discharge. When electrons are pushed from a sharp ☐ into the air, this is known as an ☐ * .

A-333

In an electric current, the first electron does not move all the way down the conductor, but only until it gets close to the next electron. In the figure, an electric current begins at A, where electrons are being added. Each electron ☐ the ones around it. However, since the force of repulsion is greater near where the electrons are being added, the force will be greater on one side of the electrons than the other, and they will tend to move along the wire, in the direction from A to ☐ $.



A-355

The unit of measurement for current is an ☐. Charge is measured in units called ☐ and time in units called ☐. One ☐ equals one ☐ per ☐.

A·I·R ©1960

a-354

ampere

a-332

repel
current

a-310

repel
large

a-288

A

A·I·R ©1960

a-267

charge

a-289

concentration of charge (or, amount of charge)

a-311

air
point
electrical discharge

a-333

repels
E

a-355

ampere
coulombs
seconds
ampere
coulomb
second

A·I·R ©1960

A-354

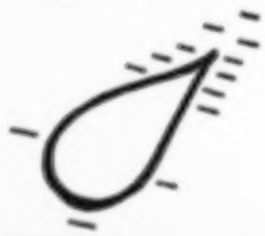
To find the current in amperes, we must count the number of coulombs of charge passing a given point in a second. One coulomb passing a given point in one second equals one ☐ of current.

A-332

Electrons are negatively charged. They tend to ☐ each other. If electrons are added at one end of a wire, they will repel other electrons in the vicinity, which then cause additional electrons to move in turn. This movement of electrons is called an electric ☐.

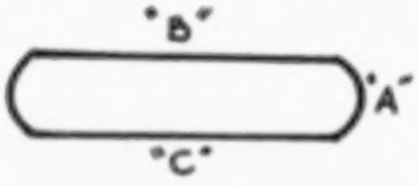
A-310

When the concentration of electrons on a negatively charged object becomes large enough, as it does at a sharp point, the electrons are so close together that they will ☐ each other with a (large/small) ☐ amount of force. This will cause some of the electrons to be pushed off the conductor into the air.



A-288

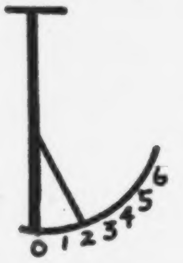
The area of greatest concentration of charge on the conductor pictured below is at point ☐.



A-I-R ©1960

A-268

The electrometer has a scale with numbers on it. When a charge is put on the electrometer, the gold leaf is repelled by the stem and will point to a number on the scale. The number indicates the relative amount of ________ on the electrometer. The ________ in the figure indicates a charge value of # ____ units.

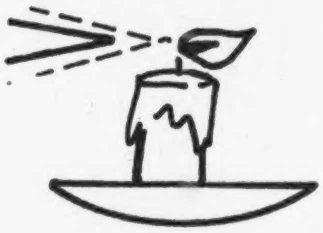


A-290

The sharper the curve at some place on a conductor, the greater will be the * ________ in that area.

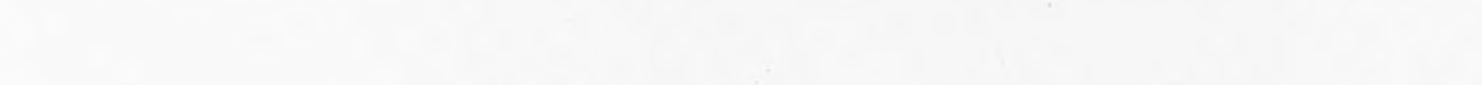
A-312

We can demonstrate electrons being pushed into the air; that is, an * ________ by pointing a sharply pointed, negatively charged object at a candle flame. The flame will actually move because of the force of the stream of ________ striking it.



A-334

Imagine a line of cars waiting for the light to turn green. A car comes up to the end and smashes against the last car, this car pushes the next, and so on, until the car at the head of the line is pushed into the intersection. This is similar to the movement of electrons in a conductor which we call an * ________.



A-356

Current refers to rate of flow, not amount of charge. The amount of charge is measured in ________. Current, on the other hand, is measured in ________.

A·I·R ©1960

a-353

rate
ampere

a-331

electric current

a-309

greatest curvature

a-287

shape of the conductor (or, object)
greater

A·I·R ©1960

(131)

a-268

charge
electrometer
2

a-290

concentration of charge (or, amount of charge)

a-312

electrical discharge
electrons

a-334

electric current

a-356

coulombs
amperes

A·I·R ©1960

A-353

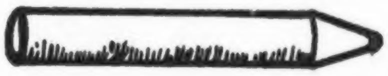
Current is the ________ at which charges flow. The unit of measurement for current is called an ampere. One ________ equals one coulomb per second.

A-331

Physicists refer to the movement of electrons along a conductor as an electric current. It is always better to use the term * ________ than "flow of electrons" or "movement of electrons".

A-309

An object sharpened to a point will have a very large concentration of charge at the sharp point. This is because the point has the * ________.



A-287

The distribution of charge on a conductor depends on the ** ________. A curved surface will have a (greater/smaller) ________ concentration of charge than a flat surface.

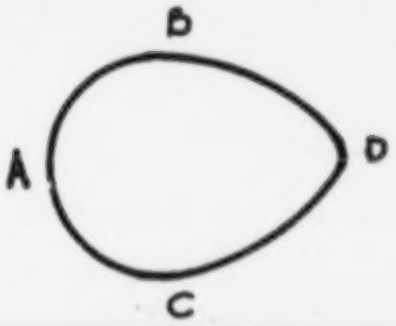
A·I·R ©1960

A-269

An ______ is used to measure relative amounts of ______. Like an electroscope, it is based on the principal that like * ______.

A-291

An oval-shaped conductor is shown in the figure. The part where there would be the greatest amount of charge is at $ ______.



A-313

The movement of electrons into the air is called an * ______.

A-335

Years ago it was thought that positive charges moved in a conductor. Now we know that only the ______ charged ______ move.

A-357

Current is measured in ______. Time is measured in ______. Charge is measured in ______.

A·I·R ©1960

a-352

coulombs
coulombs
current

a-330

electrons

a-308

the point where the curvature is the greatest (or, the point of greatest curvature)

a-286

curved ends (or, curved sides)
flat sides

A·I·R ©1960

a-269

electrometer
charge
charges repel

---

a-291

D

---

a-313

electrical discharge

---

a-335

negatively
electrons

---

a-357

amperes
seconds
coulombs

A·I·R ©1960

A-352

If there are a large number of ________ of charge passing a given point in a second, current will be high. If only a small number of ________ of charge pass the point in a second, the ________ will be low.

A-330

We know that only electrons, that is, the negative charges, can move from atom to atom. Therefore, when we speak of electric current we always mean the movement of ________.

A-308

The concentration of charge on a conductor will be greatest at ** ________.

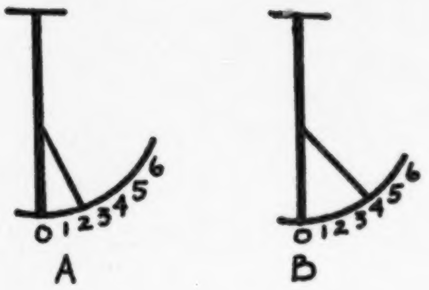
A-286

A conductor with curved ends and flat sides will have a greater amount of charge on the * ________ than on the * ________.

A·I·R ©1960

A-270

Which electrometer indicates the greatest amount of charge? ____ \$ ____ Do they indicate whether the charge is positive or negative? (yes/no) ____

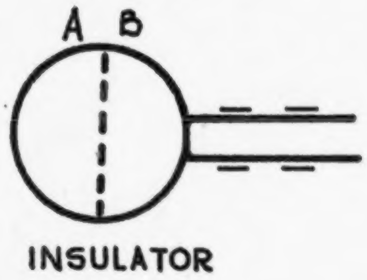


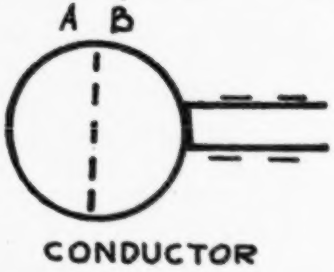
A-292

The figures below show a pith ball (insulator) and a metal ball (conductor). Side "B" of each has received a charge. How will the added charges be distributed on the insulator?

** ____

____. How will the added charges be distributed on the conductor? ** ____





A-314

If the charge is large enough, we see the effect of electrons moving into the air in the form of a spark. A spark is evidence of an * ____.

A-336

Some old text books refer to electric current as beginning at a source of positive charges. Physicists, however, know that this is wrong and that current is the flow of ____, so the flow of current begins at a source of ____ charge.

A-358

Current equals charge divided by time. If one coulomb of charge passes a given point in one second, then the current is # ____ ampere.

A·I·R ©1960

a-351

coulomb
coulomb
electrons

a-329

charges which are at rest (or, not moving)

a-307

proof-plane
electrometer

a-285

shape
curved
flat

A·I·R ©1960

a-270

B

no

a-292

The added charge (on the pith ball) will stay at the point of contact.

The added charge (on the metal ball) will (be conducted and) be evenly distributed over the ball.

a-314

electrical discharge

a-336

electrons

negative

a-358

1

A·I·R ©1960

A-351

Since a ________ is the measure of charge, it is often confused with electrons, which make up the charge. In talking about electric current, we always refer to the unit of charge, a ________, and not to ________.

A-329

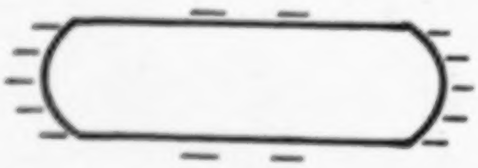
Static electricity refers to ** ________________________.

A-307

As a general rule, we can say that the greatest concentration of charge on an object will be at the point of greatest curvature. We can prove this with the aid of a ________ and an ________.

A-285

The distribution of charge on an object depends on its ________. Experimentally, we know that an object with flat sides and curved ends will have more charge concentrated on its curved surfaces. Using a proof-plane and an electrometer, it can be shown that the charge is more concentrated on the ________ parts than on the ________ parts of an object.

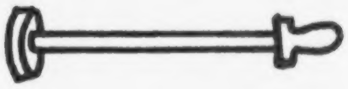


A·I·R ©1960

A-271

A proof-plane is a small metal disk supported by a rubber rod. It is used to obtain a sample of charge and carry it from one object to another.

Touching a proof-plane to a charged ball and then to an electrometer will indicate the relative amount of ______ which was present on the ball.



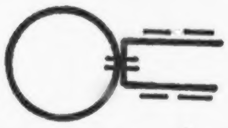
A-293

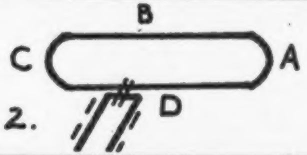
The conductors below have all received a charge. Describe how the charges will be distributed on each object.

1. **

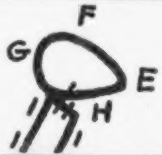
2. **

3. **


1.



2.

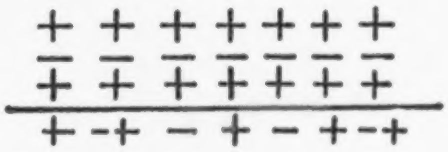


3.

A-315

Winds moving in opposite directions create ______ electricity just as we do when we rub amber with fur. The ground has a neutral charge.

Above the ground there are layers of positively charged air and layers of negatively charged air.



A-337

An electric current is a movement of ______ beginning where there is the greatest concentration of ______ charge.

A-359

Current = $\frac{\text{charge}}{\text{time}}$. If 6 coulombs pass a given point in 2 seconds, the current is * ______.

A·I·R ©1960

a-350

coulombs
second
rate

---

a-328

static electricity
electric current

---

a-306

proof-plane
electrometer
proof-plane
electrometer

---

a-284

shape of the conductor
evenly distributed

A·I·R ©1960

a-271

charge

a-293

1. They will be evenly distributed over the object.
2. There will be more charge at A and C than B and D.
3. The most charge will be at E, the least charge at F and H.

a-315

static

a-337

electrons
negative

a-359

3 amperes

A·I·R ©1960

A-350

The number of ________ of charge passing a given point in one ________ will give us the ________ of flow of electric charges; that is, the amount of electric current.

A-328

When electric charges are in motion they form an electric current. When electric charges are at rest, we call this * ________. When electric charges are moving an * ________ exists.

A-306

To determine the distribution of charges on a conductor, we touch each point on the surface with a ________ and carry charges with it to an ________. Between each test we must "ground" both the ________ and the ________.

A-284

The distribution of charges on a conductor depends on the ** ________ ________. A metal ball will have * ________ charges.

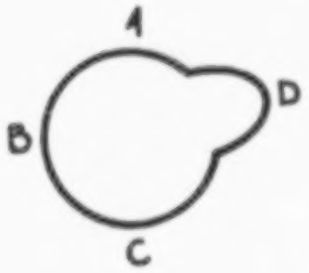
A·I·R ©1960

A-272

To sample the charges on an object or transfer them from one object to another, we use a small metal disk attached to an insulated handle called a $\boxed{}$.

A-294

As a general rule, we can say that the greatest concentration of charge on a conductor will be at the point of greatest curvature. An electroscope will show that the greatest charge is at point $\boxed{\$}$ on this object (a conductor).



A-316

Lightning occurs when electrons from a negative layer jump to a positive or neutral region. If this happens between two layers of air, it is harmless; but if it happens between a layer of air and the earth, lightning may strike buildings and trees, etc. Lightning is a violent form of $\boxed{*}$.

A-338

To find the rate of traffic on a street, we would count the number of cars passing a particular point on the street in a unit of time, such as, five cars per minute, or ten cars per minute. If we know how many cars pass a particular point every minute, we have found the $\boxed{}$ of traffic flow.

A-360

As we learned in studying Coulomb's Law, the letter "q" stands for charge. In writing the equation for current, "I" stands for current, and "t" for time.

$\text{Current} = \frac{\text{charge}}{\text{time}}$, or in symbols, $\boxed{\$} = \frac{q}{\boxed{\$}}$.

A·I·R ©1960

END OF UNIT

---

a-349

coulombs
second

---

a-327

static

---

a-305

ground
come together

---

a-283

sphere (or, ball)

A·I·R ©1960

a-272

proof-plane

a-294

D

a-316

electrical discharge

a-338

rate

a-360

$I = \frac{q}{t}$

A·I·R ©1960

END OF UNIT

A-349

To find the rate of flow of charge we use the coulomb as the unit of charge and a second as the unit of time. Therefore, the current is equal to amount of charges, expressed in ________ , per ________ .

A-327

Static means at rest or not moving. When electric charges are at rest we call this ________ electricity.

A-305

If an electrometer shows a charge, we can ________ it by touching it to the ground or any large conductor. We know it has been neutralized when the leaves ** ________ .

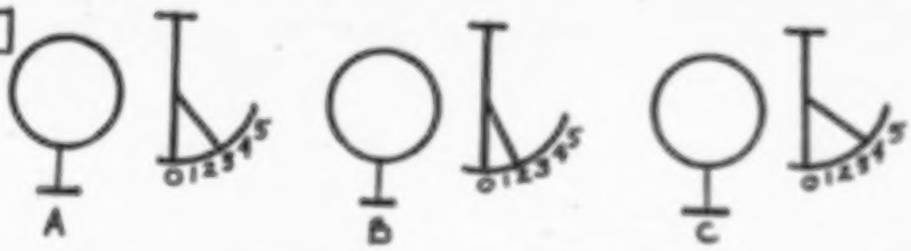
A-283

Using a proof-plane and an electrometer, we would find that charges are evenly distributed over the surface of a ________ .

A·I·R ©1960

A-273

Three metal balls have been tested with a proof-plane and an ☐. In the figure, which ball has the greatest amount of charge? $

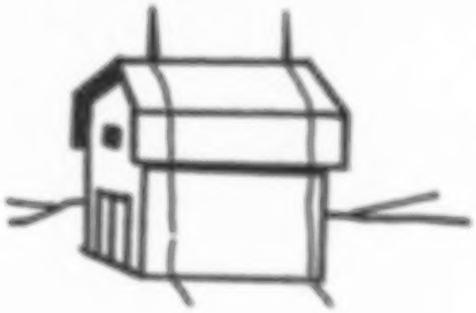


A-295

We use negatively charged conductors as examples of the distribution of charge because it is the negatively charged ☐ that move, not the positive charges.

A-317

Lightning rods are used to protect buildings from being struck by lightning. Lightning rods consist of a metal pole attached to the building and a wire leading from the pole to the earth. The wire and pole are both conductors; that is, they will conduct ☐.



A-339

To find the rate at which electrons flow, we count the number of charges passing a given point in a given time. We ordinarily use one second as the time interval. The number of charges passing a given point in a second will give the ☐ of electron flow. This rate is called electric current. An * is the rate at which electrons flow.

A-361

$I = \frac{Q}{t}$. For example, if 6 coulombs pass a given point in 3 seconds then the current will be two amperes. If 12 coulombs pass a given point in 3 seconds, then current (I) will be * .

A·I·R ©1960

a-370

the tale of the movement of charge along a conductor.

a-348

coulomb

a-326

static

Van de Graaf generator

Van de Graaf generator

a-304

repel

a-282

shape

conductor (or, object)

evenly distributed

the charges are evenly distributed (are the same at all points)

A·I·R ©1960

a-273

electrometer
(ball) C

a-295

electrons

a-317

electrons (or, charge, electricity)

a-339

rate
electric current

a-361

4 amperes

A·I·R ©1960

A-370

An electric current is ** ____________________.

A-348

In studying Coulomb's Law on the force of attraction or repulsion between two charges, we learned that the unit of measurement of charge is called a ________.

A-326

A mechanical way of generating ______ electric charges is by using a * ____________. Physicists use the * ____________ rather than rubbing amber with fur, glass with silk, etc.

A-304

An electrometer shows a charge when the leaves move apart. When an electrometer is charged, the leaves ______ each other because they receive a like charge.

A-282

The way charges are distributed on a conductor depends on the ______ of the ______. The charges on a sphere are * ____________. If we tested a charged metal ball at several points we would find that ** ____________________.

A·I·R © 1960

153

A-274

To compare the charge on a metal rod and a metal ball, we remove charge from these objects with a ______ and carry them to an electrometer. The scale on the ______ will indicate the amount of ______ on each object.

A-296

The distribution of positive charge on conductors of various shapes is the same as negative charges. That is, a sharp curve will have a * ______ of positive charge than a flat surface, and so on.

A-318

During a storm the lower level of air develops a positive charge. The positively charged layer of air ______ electrons from the earth which travel up the wire to the pole.

A-340

When electric charges are at rest this is known as ______ electricity. Electric charges in motion are called an * ______.

A-362

The formula for finding the current flowing in a conductor is $I = \frac{\$}{\$}$.

In words, the formula would read ** ______.

A·I·R ©1960

4

a-369

rate

(I) = $\frac{q}{t}$

a-347

Coulomb's

a-325

discharge

a-303

the ground (or, the earth, a large conductor)
ground (or, earth, conductor)
proof-plane

a-281

proof-plane
the same (or, identical)

A·I·R ©1960

155

a-274

proof-plane
electrometer
charge

---

a-296

greater concentration (or, greater amount)

---

a-318

attracts

---

a-340

static
electric current

---

a-362

$I = \frac{q}{t}$

current (in amperes) equals charge (in coulombs) divided by time (in seconds)

A·I·R ©1960

A-369

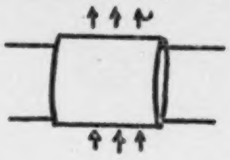
An electric current is the ☐ at which electrons move along a conductor. The formula for current is I = ☐ $.

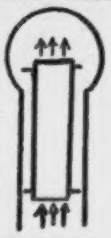
A-347

The unit of measurement of charge is called a coulomb. You used these units of charge before in studying the force of attraction or repulsion between two charges in terms of ☐ Law.

A-325

Near the top of the belt are more needle points. As the electrons reach the top of the belt, they are picked off the belt by a strip of metal. The electrons are then conducted to the top needle points. The points at the top ☐ electrons and they move onto a hollow metal ball covering the apparatus.



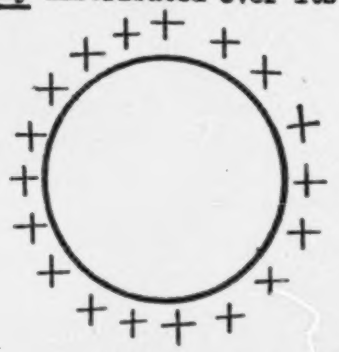


A-303

To ground a proof-plane having a positive charge, we touch it to ☐ *.
In this case, electrons will flow from the ☐ to the ☐.

A-281

A conductor shaped like a sphere will have charges evenly distributed over its surface. If we sampled the charges on a charged metal ball with a ☐, we would find that the reading on the scale of an electrometer would be ☐ * for any part of the ball.



A·I·R ©1960

A-275

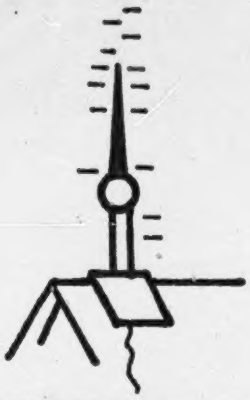
An object which does not conduct charge is called an ______. If an insulator is touched with a charged rod, the charge on the object will remain at the point of contact. Electrons cannot move through an ______.

A-297

A positively charged object is one with more ______ charge than ______ charge. Since positive charges do not move in a conductor, the concentration of charge on a positively charged object depends on the movement of ______.

A-319

By sharpening the top of the pole to a point, we can cause the electrons to discharge into the air. In this way, we neutralize the air in the vicinity of the pole by adding electrons to the ______ charged air.



A-341

Only the ______ charged ______ can move. ______ charges never move in a conductor. An electric current, then, is produced by the movement of ______.

A-363

Current can be measured with an instrument called an ammeter. An ______ measures current in units called amperes.

A·I·R ©1960

a-368

electrons
current
negatively
positively

a-346

coulomb

a-324

charge (or, electrons)

a-302

ground
the ground (or, a ground, the earth, a large conductor)
ground (or, earth, conductor)

a-280

electrometer
proof-plane

A·I·R ©1960

159

a-275

insulator
insulator

a-297

positive
negative
electrons

a-319

positively

a-341

negatively
electrons
positive
electrons

a-363

ammeter

A·I·R ©1960

A-368

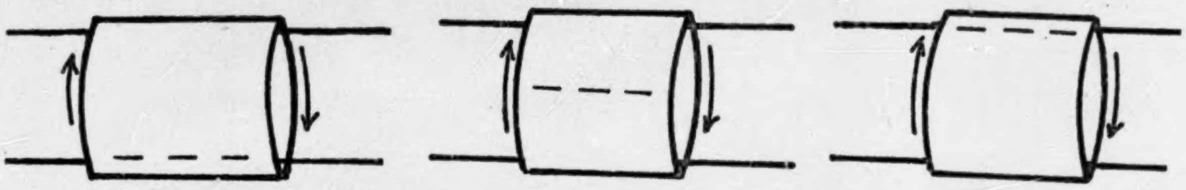
Current is actually the movement of ________ from one point to another. If a negatively charged object and a positively charged object were connected with a conductor, the movement of electrons or ________ will flow from the ________ charged object to the ________ charged object.

A-346

A unit of charge is a coulomb. Just as a pound stands for a large number of beans, a ________ of charge stands for many electrons.

A-324

The belt is an insulator and will not conduct ________, but the charges deposited on the belt will be carried along by the belt as it moves.



A-302

In order to ________ an electrometer which has been given a negative charge we attach it to ________. The surplus of electrons from the negatively charged electrometer will flow to the ________.

A-280

We can measure the distribution of charges on a charged metal ball with an ________. To sample and carry the charge we use a ________.

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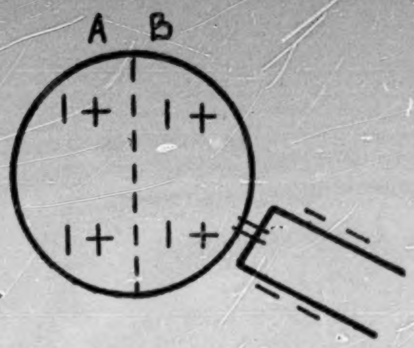
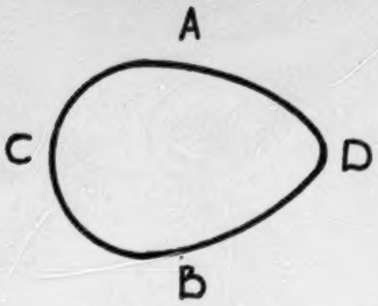
A-276

If an insulator is given a charge, the charge will not be conducted, but will remain at the point of contact. In the figure, a pith ball has been charged on side B. If each side of the pith ball is tested with an electrometer, side [$] will give the higher reading on the scale.



A-298

On an egg-shaped conductor which has been positively charged, the smallest concentration of electrons will be at D, the greatest at A and B. Therefore, [$] will have the greatest amount of positive charge.



A-320

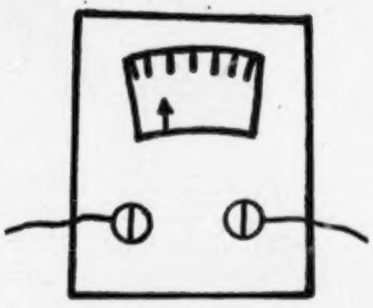
Lightning rods prevent lightning. They do not "collect" lightning as many people think. They prevent lightning from occurring by [**].

A-342

When electrons are added at one end of a conductor, they repel other electrons in the conductor, causing a movement of electrons. This [ ] of electrons along the conductor is known as an [*].

A-364

To measure the current flowing through a wire, the wire is cut and the current is allowed to flow through the ammeter. A needle points to the number on the scale indicating the current in units called [ ].



AMMETER

A·I·R ©1960

a-367

coulombs
amperes
ammeter

---

a-345

coulombs

---

a-323

generator
discharge

---

a-301

ground (or, earth)
neutral

---

a-279

electrometer
shape

A·I·R ©1960

a-276

B

a-298

D

a-320

discharging electrons into the positively charged air.

a-342

flow
electric current

a-364

amperes

A·I·R ©1960

A-367

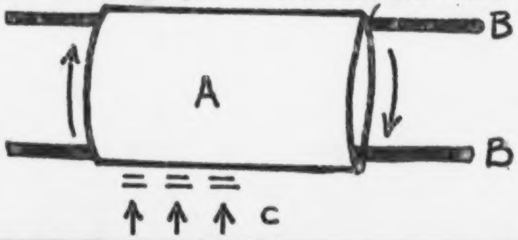
Charges are measured in ☐. Current is measured in ☐. To measure current we can use an instrument called an ☐.

A-345

Charge is measured in units called coulombs. A unit of measure means a standard amount of something. For instance, we measure sugar in units called cups, milk in units called quarts, and electric charge in units called ☐.

A-323

A Van de Graaf ☐ consists of a belt (A) on pulleys or shafts (BB). The belt is an insulator. A motor drives the belt around the pulleys. Near the belt are needle points (C). The needle points are connected to a source of negative charge (a battery). The sharp needle points ☐ electrons on to the belt.



A-301

When an object is grounded, excess electrons move from one object to the other until both objects are neutral. A positively charged object when touched to the ground will gain electrons from the ☐ until the object has become ☐.

A-279

Using a proof-plane to sample the charge and an ☐ to measure the charge, we can find out how charges are distributed on the surfaces of conductors of different shapes. The distribution of charge on a conductor depends on its ☐.

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A-277

The distribution of charge on an insulator depends on where the charge was placed because insulators cannot [*].

A-299

Each time an electroscope or electrometer is used, we must "neutralize" it before it is used again. This is called grounding. To ground an electrometer, we attach it to a large conductor (a large piece of metal, a long wire, or the earth). If the electrometer was negatively charged, the extra electrons move off the electrometer on to the conductor. When we want to make an electrometer neutral, we touch it to a large conductor; that is, we [ ] it.

A-321

Static electricity is generated when a glass rod is rubbed with silk or an amber rod is rubbed with fur. A Van de Graaf generator is a machine for doing the same thing. A Van de Graaf generator produces [*].

A-343

The amount of charge flowing past a given point in one second gives us the [ ] at which the electrons are flowing.

A-365

We can measure current by using an instrument known as an [ ].

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a-366

$I = \frac{q}{t}$

a-344

charge (or, electrons)
second

a-322

static electricity
Van de Graaf generator

a-300

ground
conductor

a-278

electrometer

A·I·R ©1960

a-277

conduct charges

---

a-299

ground

---

a-321

static electricity

---

a-343

rate

---

a-365

ammeter

A·I·R ©1960

A-366

We can calculate current using the formula ☐ $

A-344

The current or rate of flow is calculated as the amount of ☐ passing a given point in a ☐.

A-322

A Van de Graaf generator produces ☐ *. Instead of rubbing an amber rod with fur, we can use a ☐ *.

A-300

A proof-plane must also be grounded between each use. To ☐ a proof-plane, we also touch it to a large ☐.

A-278

When charges are placed on a conductor, the charges move over the surface of the conductor. The distribution of charge on a conductor depends on the shape of the conductor. The distribution of charges on different shapes of objects can be compared by using a measuring instrument called an ☐.

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(171)

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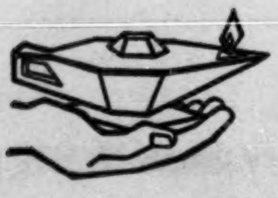
UNIT FOUR

DIFFERENCE OF POTENTIAL

Steps A-371 through A-494



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UNIT ENDS HERE

A-371

A flow of current cannot occur unless there is a difference of potential between two objects. Charged objects have a certain electrical potential, and in order for current to flow between any two objects, there must be a difference of electrical [ ] between them.

A-397

When we speak of the direction in which current will flow between two charged objects, we speak of the difference of [ ] between them.

A-423

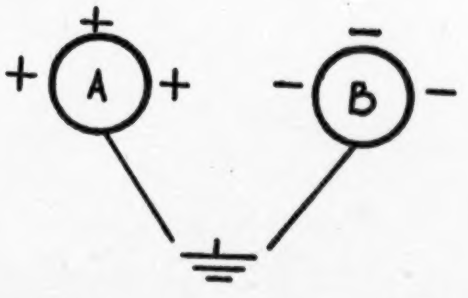
We can indicate areas of positive or negative potential with the symbols [$] and [$] respectively. The symbol for ground is [$].

A-449

A volt is the unit of potential difference. When the number of [ ] is large we know there is a large difference of potential.

A-475

Suppose we have a positive (A) and a negative (B) object and connect them both to ground. Current will flow from [$] to ground and from ground to [$].



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a-474

a large potential difference

a-448

coulombs
amperes

a-422

ground
zero

a-396

zero

A·I·R ©1960

a-371

potential

---

a-397

potential

---

a-423

+

-

⏚

---

a-449

volts

---

a-475

B

A

A·I·R ©1960

A-474

"+" or "-" with respect to voltage tells us the direction in which current will flow. The number of volts tells us how large the difference in potential is. A large voltage means [**].

A-448

We measure charge in units called [ ] and current in units called [ ]. We measure potential difference in units called volts.

A-422

⏚ is the symbol for [ ]. The potential of ⏚ is always [ ].

A-396

Objects are said to have positive or negative potential in relation to ground which is at [ ] potential.

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A-372

A flow of current cannot occur unless there is a difference of potential between two objects. If two objects have the same [   ], current will not flow between them; current will not flow unless there is a [*] between the objects.

A-398

A positively charged object contains electrons as well as positive charges. However, a positively charged object contains more [   ] charges than [   ].

A-424

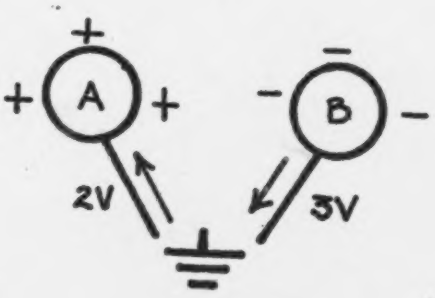
We use the symbols "+" and "-" to indicate areas of positive and negative potential. Considering only charged objects; that is, objects or areas with other than zero potential, electrons will flow from (use symbols) [$] to [$] areas.

A-450

Any time current flows between two points, we know there is a potential difference between them. This difference in potential is measured in [   ].

A-476

Suppose the potential difference between A and ground is 2 v (volts) and between B and ground is 3 v. If we were to connect A and B directly, the potential difference would be the sum of the two voltages or [#] volts.



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a-473

flow from the object

---

a-447

there must be a difference of potential
higher
lower

---

a-421

difference of potential
conductor
electric current

---

a-395

electric current

A·I·R ©1960

a-372

potential
difference of potential

---

a-398

positive
electrons (or, negative charges)

---

a-424

-
+

---

a-450

volts

---

a-476

5

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A-473

Positive voltage means electrons will flow to the object from ground. Negative voltage means electrons will ** __________ to ground.

A-447

In order for current to flow ** __________. Current will flow from an object having (higher/lower) __________ potential to an object having (higher/lower) __________ if they are connected.

A-421

There is always a * __________ between objects of positive and objects of negative potential. When the objects are connected with a __________, an * __________ will flow.

A-395

No electric current will flow between objects with identical potential. There must be a difference of potential between two objects in order for an * __________ to flow.

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A-373

We know, of course, that current will never flow between two objects unless they are connected with a conductor. Even when they are connected, however, there will be a flow of current only when a * ______ exists.

A-399

Relative to ground, all positively charged objects have a ______ potential. One + object, however, may have a greater + potential than another + object. In this case, there will be a flow of current between the objects, if they are connected, because there is a ______ of potential between the objects.

A-425

When an object is connected to ground, the direction of electron flow indicates whether the object had + or - potential. As soon as a connection is made an * ______ will be produced.

A-451

Switching on a flashlight allows current to flow through the bulb. The potential difference on which this flow of current depends is small however. The difference in potential for a two-cell flashlight is only about 3 ______.

A-477

If we connect two objects with a conductor and current flows from one object to the other, we know that there was a * ______ between them. The current flowed from the object with (higher/lower) ______ potential to the object with * ______.

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a-472

negative voltage

a-446

higher
A (to) B

a-420

negative
positive

a-394

(A) -
(B) +

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a-373

difference of potential

a-399

positive
difference

a-425

electric current

a-451

volts

a-477

potential difference (or, difference of potential)
higher
lower potential

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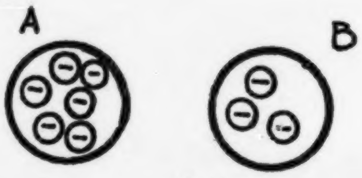
A-472

Whenever negative work is required to bring a small + test charge from ground to an object, this indicates a negative voltage. As compared with ground, a negatively charged object will always have a [*] .

A-446

The figure shows two negatively charged objects. Object A has the greater concentration of electrons, therefore it has the [ ] potential. Current will flow from object [$] to [$] if they are connected.

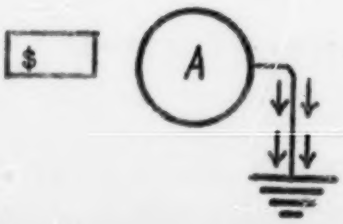


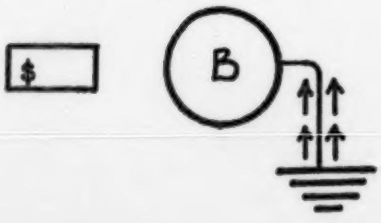
A-420

If they are connected with a conductor, current will flow to objects at zero potential from objects at [ ] potential, and from objects of zero potential to objects of [ ] potential.

A-394

Below are two objects. Label the objects, using symbols to indicate either positive or negative potential.

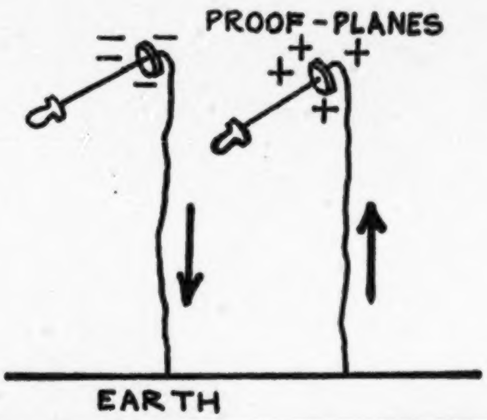




PBI
A·I·R ©1960

A-374

The earth, or the ground, is said to have zero potential. If an object is connected to the ground and electrons flow from the ground to the object, the object is said to have had positive potential. If electrons flow from the object to the ground, the object is said to have had negative ______.



A-400

Two objects may be negatively charged but one object may have a greater negative potential than the other. Thus, there will be a ______ of potential between these two objects, and if they are connected, ______ would flow.

A-426

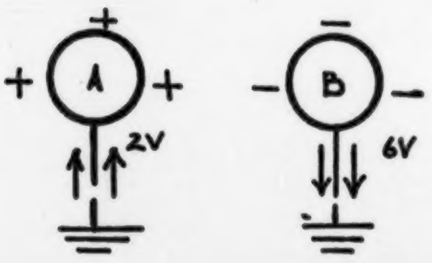
When an object is connected to ground, and electrons move from ground to the object, we know the object had * ______.

A-452

The flow of current in your house is based on a larger voltage than that in a flashlight. In your house, the difference of potential is approximately 110 ______. This is a higher ______ than in a flashlight.

A-478

The figure shows two charged objects. For each object, the voltage with respect to ground and the direction in which current would flow, is given. If A and B were connected to each other, current would flow from $ ____ to $ ____. Between A and B there is a potential difference of # ____ volts.



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a-471

negative
(V) = $\frac{W}{Q}$

a-445

lower
toward

a-419

difference of potential
electrons
concentration of electrons

a-393

positive potential
negative potential

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a-374

potential

---

a-400

difference
current

---

a-426

positive potential

---

a-452

volts
voltage (or, potential difference)

---

a-478

B (to) A
8 (v)

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A-471

To calculate the potential between a negative object and ground, we carry a small + test charge from ground to the object. Since the + test charge will be attracted, work will be involved, yet the formula V = $ is used.

A-445

As compared with an object with negative potential, an object with positive potential has a (higher/lower) potential. This means current will flow (toward/away from) the object with positive potential.

A-419

Current flows between two connected objects when there is a * between them. Current will flow from the object having the greatest over-all concentration of to the object having a lower over-all

---

A-393

We indicate positive or negative potential with respect to ground using the symbols "+" and "-". An object labeled + has * . An object labeled - has * .

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A-375

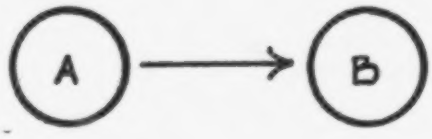
The earth, or ground, is said to have zero __________. In other words, it is electrically neutral.

A-401

The amount of potential that a given object has depends on many things, its shape, size, and the amount of charge placed on it. In general, however, we can say that a charged object having a greater concentration of electrons than another negatively charged object, also has greater negative __________.

A-427

If electrons will flow from object A to object B, we say object A has a greater over-all __________ of electrons than B.

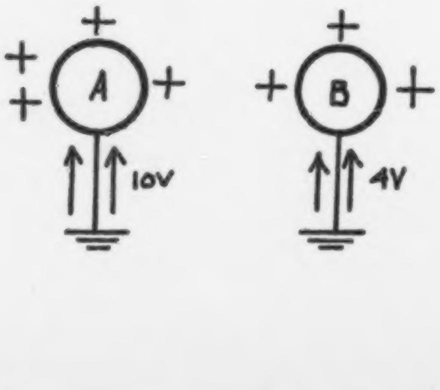


A-453

A high voltage means a large * __________. A low __________ means a small potential difference. Voltage always refers to the * __________ between objects or between an object and ground.

A-479

To find the potential difference between two objects having like charges, you subtract the smaller potential from the larger as measured with respect to ground. In the figure, the potential difference between A and B is # ______ volts. Since current would flow from B to A, A has a __________ potential than B.



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a-470

$(V=)\ \frac{W}{Q}$

a-444

higher
the object to ground

a-418

current (or, charge, electrons)
potential

a-392

negative potential
ground

A·I·R © 1960

a-375

potential

a-401

potential

a-427

concentration

a-453

potential difference (or, difference of potential)
voltage
potential difference (or, difference of potential)

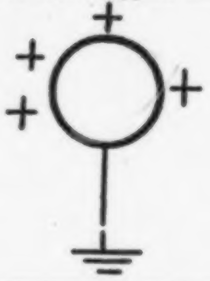
a-479

6 (v)
lower

A·I·R ©1960

A-470

To calculate the difference of potential between a positive object and ground, we carry a small + test charge from ground to the object. Using the formula, V = [$] we could find the potential of the object.



A-444

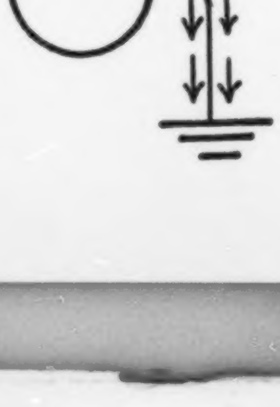
As compared with ground, a charged object with negative potential has a (higher/lower) [ ] potential. This means current will flow from [*].

A-418

In order to have a flow of [ ] we must have a difference of [ ]

A-392

The object pictured below had a [*] before it was connected to [ ].



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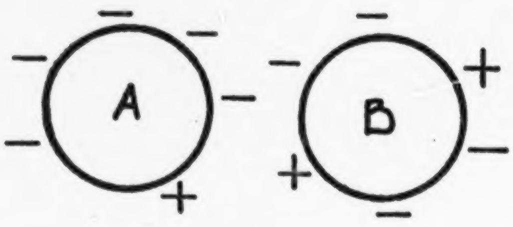
A-376

An object has positive potential before it is connected to the ground. After it is connected, the object becomes neutralized or grounded. The object will now have [ ] potential, the same potential as ground.

A-402



Current tends to flow from objects having a greater concentration of electrons to objects where there is a smaller concentration. The figure shows two spheres. Sphere A has a greater concentration of electrons. If the two spheres are connected, [ ] will flow from [$] to [$].

A-428

Potential can be thought of as a pressure or force which is necessary to produce an electric [ ]. When the potential on two objects is the same, no [*].

A-454

To measure potential, we calculate how much work would be necessary to carry a very small positive test charge from a far away point to a charged object. Because like charges [*], work will be required if the object has a positive charge.

A-480

To find the difference of potential between two objects, with unlike charge, we find the potential of each in volts, relative to ground, and add the two potentials together. The resulting sum is the [*] between the two objects measured in [ ].

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END OF UNIT

a-469

positive
negative

a-443

higher
lower

a-417

ammeter
amperes

a-391

ground
positive
ground

A·I·R ©1960

195

a-376

zero

a-402

current (or, electrons)
A (to) B

a-428

current
current will flow

a-454

repel each other

a-480

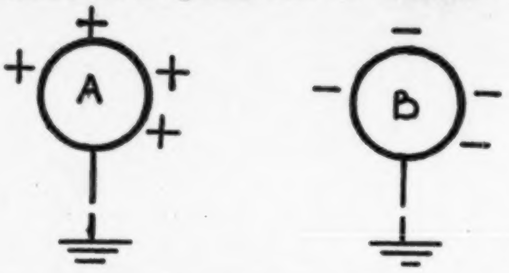
potential difference (or, difference of potential)
volts

A·I·R ©1960

END OF UNIT

A-469

In the figure, both objects have a difference of potential in relation to ground. A has ______ potential.
B has ______ potential.



A-443

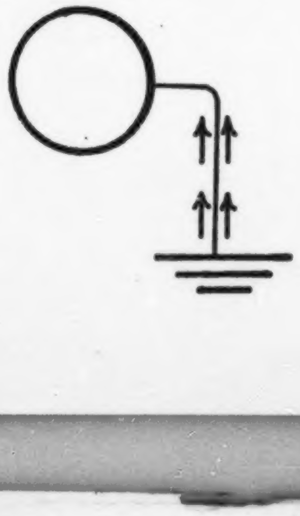
Current flows from an object with (higher/lower) ______ potential to an object with (higher/lower) ______ potential.

A-417

An instrument used to measure current is an ammeter. The ______ measures current in units called ______.

A-391

The figure shows an object connected to ______. The arrows indicate the direction of the electron flow. We would say therefore that the object had a ______ potential before it was connected to ______.



A·I·R ©1960

A-377

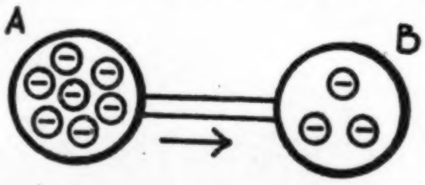
An object with negative potential is touched to the ground. Current will flow from the [ ] to the ground. As soon as the object is neutralized, there will be no difference in [ ] and current will stop [ ].

A-403

When a difference in potential exists, this means current will flow from the object with the greater over-all concentration of electrons to the object with a [*].

A-429

The figure shows a greater concentration of electrons on sphere A than B; thus there is a [*] between the two objects. If the two spheres are connected with a conductor, some [ ] will move through the conductor from sphere [$] to [$].



A-455

In physics, work can be positive or negative. When force is required to move an object, work is positive. For instance, to push an auto up a hill, [ ] work is required.

A-481

We measure potential in terms of the joules of [ ] involved in carrying a small + test [ ] to an object from ground or from a distance.

A·I·R ©1960

a-494

coulombs
charge
volts

a-468

no difference in potential (or, the same potential)

a-442

ground
lower

a-416

$I = \frac{q}{t}$

charge (in coulombs) divided by time (in seconds)

a-390

ground

A·I·R ©1960

a-377

object
potential
flowing

---

a-403

smaller (over-all) concentration of electrons

---

a-429

difference of potential (or, potential difference)
electrons
A (to) B

---

a-455

positive

---

a-481

work
charge

A·I·R ©1960

A-494

We abbreviate amperes as "amps", or sometimes just "a.". In a formula, however, we use the symbols "I" for amperes of current, Q for [ ] of [ ], and V for [ ] of potential difference.

A-468

Any time there is a difference in potential between two objects, there is some voltage between the two objects. There is no voltage when there is [*].

A-442

Most physicists use the terms negative potential and positive potential only when comparing a charged object with [ ]. When they compare two charged objects with each other they use the terms higher and lower potential. Electrons will flow from the object with higher potential to the object with [ ] potential.

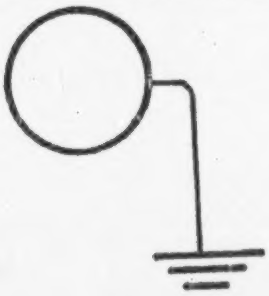
A-416

The formula for finding current is, [$]. In words, this means current equals

[*].

A-390

⏚ is the symbol for ground. When we see a diagram with this symbol, we know there is a connection to ground. The figure at the right shows an object connected to [ ].

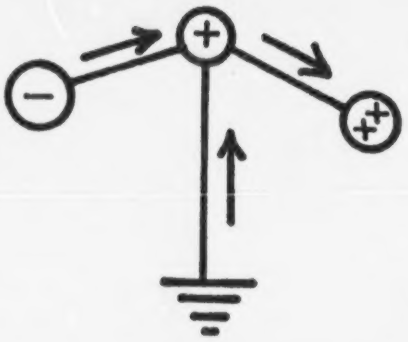


A·I·R ©1960

A-378

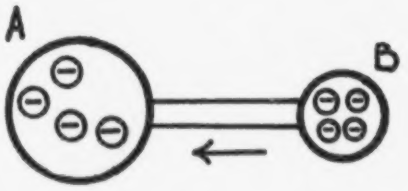
The earth or "ground" is always at [*]. With respect to a neutral object there is [*] between the object and ground.

A-404



It is a mistake to think that, because an object is positively charged, current will always flow toward it. If we connect the object to ground or to a negatively charged object, current will [ ] toward it but, if we connect it to an object having even a smaller concentration of electrons, current will flow [ ] from our object.

A-430



Suppose two spheres were each given the same amount of negative charge, but sphere A was much larger than sphere B. As the figure shows, the concentration of electrons on sphere A would be much smaller than on sphere B. Thus, current will flow from B to A because there is a [*] between the two objects.

A-456

To carry a small + test charge to a positively charged object even from a long distance away, force is required because the objects [ ] each other. To do this involves [ ] work.

A-482

Potential is measured in units called [ ]. Charge is measured in units called [ ]. Work is measured in units called [ ].

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a-493

ammeter
current

a-467

$V = \frac{W}{Q}$

a-441

greater
smaller

a-415

current
amperes

a-389

positive (negative)
negative (positive)
zero

A·I·R ©1960

203

a-378

zero potential
zero potential difference (or, no difference of potential)

a-404

flow
away

a-430

difference of potential (or, potential difference)

a-456

repel
positive

a-482

volts
coulombs
joules

A·I·R ©1960

A-493

A voltmeter tells us how large a potential difference is present. An ________ tells us how much ________ is flowing.

A-467

The formula for volts is $ ________ .

A-441

Since current is a flow of electrons, current can only flow from objects having a (greater/smaller) ________ concentration of electrons to objects having a (greater/smaller) ________ concentration of electrons.

A-415

$I = \frac{q}{t}$ is the equation for finding ________ in units called ________ .

A-389

It is important to remember that once an object has been connected to ground it can no longer have ________ or ________ potential. An object with positive potential, when connected to ground will attract electrons until it has the same potential as ground; that is, ________ potential.

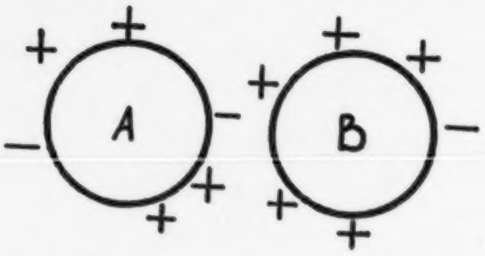
A·I·R ©1960

A-379

We determine whether an object has negative or positive potential by comparing it with the potential of the ground. In other words, the direction in which electrons would flow if an object were connected to ground determines the nature of the object's ☐ .

A-405

If object B has greater positive potential than object A, current will flow from [$] to [$] if they are connected. Even though object A has been positively charged, it has (greater/less) ☐ positive potential as compared with object B.



A-431

The potential of any charged object depends on its shape and size as well as the amount of charge placed on it. In general, however, we can say potential is related to the over-all [*] on the object.

A-457

In physics, when it would take force to prevent an object from being moved, negative work is involved. An auto rolling down a hill is an example of ☐ work.

A-483

By finding how much work is involved in carrying a small (+/-) [$] test ☐ to an object from ground or a great distance away, we can calculate ☐ difference.

A·I·R ©1960

a-492

voltmeter
current

---

a-466

$(V =) \frac{W}{Q}$

---

a-440

-
+

---

a-414

one coulomb per second

---

a-388

zero potential
zero potential

A·I·R ©1960

a-379

potential

a-405

A (to) B
less

a-431

concentration of electrons (or, charges)

a-457

negative

a-483

+
charge
potential

A·I·R ©1960

A-492

Just as a ☐ is used to measure potential difference, an ammeter is used to measure amperes of ☐.

A-466

In words, the formula for volts is: volts = $\frac{\text{joules}}{\text{coulombs}}$. In symbols this is:

V = ☐ $.

A-440

If an object with negative potential is connected to an object with positive potential, current will flow from the ☐ $ potential object to the ☐ $ potential object.

A-414

In units, one ampere equals ☐ ** .

A-388

The earth is always at ☐ * . An object having the same potential as the earth would also have ☐ * .

A·I·R ©1960

A-380

If electrons would flow from ground to the object, the object is said to have positive ☐.

A-406

When there is no difference in potential between two objects, they are said to have zero potential difference. When there is zero potential difference between two objects, no ☐ will flow if they are connected.

A-432

When there is a difference in the over-all ☐ of electrons on two objects, we know there is a ☐ * between them.

A-458

If a small + test charge is carried from a point far away to a negatively charged object, the objects will ☐ each other. Since it would require a force to keep the objects apart, this is an example of ☐ work.

A-484

Potential equals work per unit of charge in carrying a small ☐ * to the object from ground or a far away point.

Volts = ☐ $.

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a-491

voltmeter

a-465

volts
charge (in coulombs)

a-439

the object to ground
ground to the object

a-413

coulombs
second

a-387

zero potential
positive potential
negative potential

A·I·R ©1960

a-380

potential

a-406

current ("electrons" is also correct, but you should say "current" now)

a-432

concentration
difference of potential (or, potential difference)

a-458

attract
negative

a-484

+ test charge
$\frac{\text{joules}}{\text{coulombs}}$ (or, $\frac{\text{work}}{\text{charge}}$)

A·I·R ©1960

A-491

It is not necessary to calculate volts to determine potential difference. An instrument called a voltmeter can be used. A ______ tells us the size of the potential difference between two charged objects.

A-465

In symbols, the formula for volts is $V = \frac{W}{Q}$. V stands for ______, W for work (in joules) and Q for ______.

A-439

If an object having negative potential is connected to ground, current will flow from * ______. If an object having positive potential is connected to ground, current will flow from * ______.

A-413

Charge is measured in units called coulombs. Current is computed as the number of ______ of charge passing a given point per ______.

A-387

The earth has * ______. An object which attracts electrons from ground has * ______. An object from which electrons will flow to ground has * ______.

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A-381

Electrons will tend to flow to an area where there are less electrons. A positively charged object lacks some ________, therefore, ________ will tend to flow into a positively charged object.

A-407

A negatively charged object contains some positive charges as well as electrons. However, a negatively charged object contains more ________ than * ________.

A-433

The flow of current produced by connecting an object having + or - potential with ground will soon reduce the difference of potential between the object and ground to ________.

A-459

When a positive and a negative charge come together, ________ work is involved. If we bring two positive or two negative charges together, ________ work will be involved.

A-485

Potential is measured in ________ relative to ground. Difference of potential is also measured in ________.

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a-490

potential difference (or, difference of potential)

$V = \frac{W}{Q}$

---

a-464

volts

---

a-438

ground (or, earth)

---

a-412

current

---

a-386

current would flow from the object to the ground if they were connected

A·I·R ©1960

a-381

electrons
electrons

a-407

electrons
positive charges

a-433

zero

a-459

negative
positive

a-485

volts
volts

A·I·R ©1960

A-490

A volt refers to the [*] between two objects. The formula for volts in symbols is [$].

A-464

A volt is defined as the number of joules required to carry a small + test charge to a charged object divided by the size of the test charge, measured in coulombs. The formula is [ ] = $\frac{\text{joules}}{\text{coulombs}}$

A-438

When we talk about a charged object having positive or negative potential, we mean the potential of the object with respect to [ ].

A-412

The number of charges passing a given point in a second is the way we compute [ ].

A-386

Negative potential means [**].

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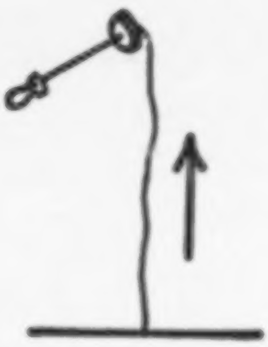
A-382

An object into which electrons will flow if grounded or connected to the ground, has a * ________.



A-408

Regardless of the sign of the charge on each of two objects, if there is a difference in ________ between them, current * ________ if they are connected.

A-434

When there is zero potential difference between two objects, * ________ ________ if the objects are connected with a conductor.

A-460

We measure potential in terms of how much work is involved in carrying a small + test charge to an object from very far away. Carrying the small + test charge to a positively charged object involves (positive/negative) ________ work.

A-486

To calculate potential we find out how much work is required to carry a small * ________ to an object from ground.

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a-489

negative

a-463

joules

a-437

less negative potential (or, zero potential, positive potential)
current will not flow (or, no current will flow)

a-411

electric current

a-385

negative

A·I·R ©1960

a-382

positive potential

a-408

potential
will flow

a-434

current will not flow (or, no current will flow)

a-460

positive

a-486

+ test charge

A·I·R ©1960

A-489

When it requires force to keep a small + test charge from being carried from ground to an object, ________ work is involved.

A-463

We measure work in units called joules (pronounced "jools"). More ________ of work are required to deposit a large + test charge on a positively charged object than to deposit a small + test charge.

A-437

Current always flows from the object with greater negative potential to the object with * ________. If there is zero potential difference ** ________.

A-411

The flow of charge along a conductor is called an * ________.

A-385

If we have an object connected by a conductor to ground and electrons flow from the object to ground, the object is said to have had ________ potential before the connection was made.

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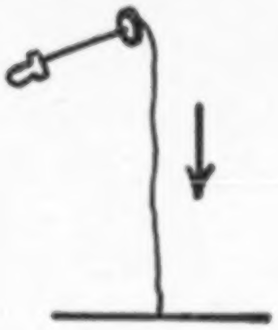
A-383

Potential always refers to the charge on an object relative to the ground. Current will flow from an object with negative __________ to the __________. Any conductor that has been charged negatively has a * __________.



A-409

Objects from which electrons will flow to ground are said to have * __________. Indicate the direction in which current will flow for each object in the figure.

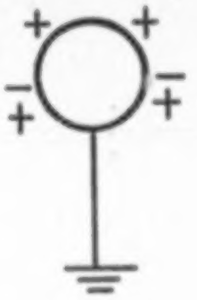


FIG. 1

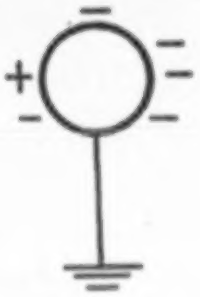


FIG. 2

A-435

Two identical objects having equal over-all concentrations of negative charge have * __________ between them. Current only flows if there is a * __________ between the objects.

A-461

To measure potential we have to calculate how much __________ would be necessary to carry a very small + test charge from a point far away to an object.

A-487

To calculate the potential of an object we find how much work is required to ** __________.

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a-488

positive

---

a-462

repel
positive
attract
negative

---

a-436

smaller concentration of electrons (or, negative charge)

---

a-410

difference of potential (or, potential difference) between them
no difference of potential (or, zero potential difference)

---

a-384

potential

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a-383

potential
ground
negative potential

---

a-409

negative potential

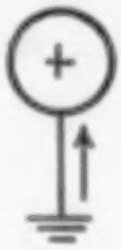
FIG. 1

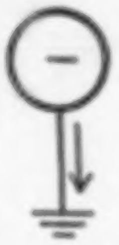
FIG. 2

---

a-435

no difference of potential (or, zero potential difference)
difference of potential

---

a-461

work

---

a-487

carry a small + test charge to the object from ground (or, from a far away point)

A·I·R ©1960

A-488

When it requires force to carry a small + test charge to an object from ground, we say that ______ work is involved.

A-462

A positively charged object will ______ the + test charge so ______ work is required to bring them together. A negatively charged object will ______ the + test charge so ______ work is required.

A-436

An object may have current flowing into it and still have negative potential. This is because the object has a ** ______ than another object to which it is connected.

A-410

Current will flow between two connected objects as long as there is a * ______. When current stops flowing, we know there is * ______ between the two objects.

A-384

It is important to know whether an object is charged positively or negatively, when talking about static electricity. When talking about electric current, however, it is important to know whether an object has positive or negative ______.

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(225)
X

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

(227)
X
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UNIT FIVE

BATTERIES AND CIRCUITS

Steps A-495 through A-591

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

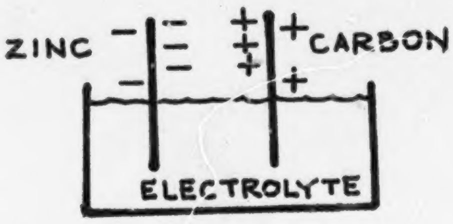
UNIT ENDS HERE

A-495

In order to have a continuous flow of water going through a pipe, a continuous supply of water is needed at one end, and an opening for the escape of the water at the other end. If there is a continuous supply of water at one end, but no opening at the other end, the water cannot escape and the ______ of water will stop.

A-515

The cell now contains a negatively charged electrode and a positively charged electrode. This whole process takes place at one time. The chemical energy of the cell has been changed into ______ energy.



A-535

Many dry cells have a voltage of 1.5 v. This means that the * ______ ______ between the electrodes produced by chemical action is 1.5 v.

A-555

Using a battery to establish a difference of potential, current will flow from the negative terminal or ______ to the ______ terminal or ______ if they are connected with a conductor.

A-575

Three cells which produce a potential difference of 1.5 v each, when connected in ______, will have a combined voltage of 4.5 v.

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a-574

series

a-554

electrons

a-534

negative
positive
current (or, electrons)

a-514

negative
positively

A·I·R ©1960

a-495

flow

35

a-515

electrical

a-535

difference of potential (or, potential difference)

a-555

cathode
positive
anode

a-575

series

A·I·R ©1960

A-574

Connecting two cells in series; that is, connecting the anode of one cell to the cathode of the other, will increase the total potential difference to the sum of the two cells. Two 1.5 v cells in ☐ will have a total potential difference of 3.0 v.

A-554

Conductors are necessary to establish a flow of current. When current does flow, it flows from a source of electrons to a point where there is a smaller concentration of ☐.

A-534

When a conductor is attached to the negative and positive terminals, electrons will flow from the ☐ terminal to the ☐ terminal. The difference of potential between the two terminals is necessary for the flow of ☐ to occur.

A-514

The positively charged H ions in the electrolyte attract ☐ charges from the carbon plate. The carbon plate loses some electrons in the process and it becomes ☐ charged.

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A-496

In order to have a continuous electric current, we must have a continuous supply of electrical energy. One way to obtain this supply is by means of a battery. A continuous supply of electrical energy can be obtained from a ________.

A-516

In a voltaic cell, chemical action between the acid, called the ________ and the plates, called the ________, causes one plate to be charged ________ and the other to be charged ________.

A-536

The chemical action of zinc, carbon and the paste used in most dry cells produces a * ________ of 1.5 v. The zinc electrode, which becomes negatively charged, is the ________ and the carbon electrode, which becomes positively charged, is the ________.

A-556

The path along which current flows from a cathode to an ________ is called a circuit. A circuit exists when there is some path along which the ________ can flow.

A-576

To get a large difference of potential, we connect several cells in ________. The total voltage obtained is the sum of the voltages of the individual ________.

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a-573

sum

a-553

conductors

electric current

a-533

electric current

a-513

negatively

A·I·R ©1960

a-496

battery

---

a-516

electrolyte
electrodes
positively (negatively)
negatively (positively)

---

a-536

difference of potential (or, potential difference)
anode
cathode

---

a-556

anode
current

---

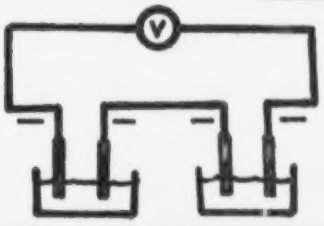
a-576

series
cells

A·I·R ©1960

A-573

Two cells connected as shown in the figure form a series circuit. The total difference of potential in a series circuit is always the ______ of the cell voltages.



A-553

As you remember, electric charges will only flow along certain materials called ______. This flow of electric charge is called an * ______.

A-533

When the energy of a storage battery is used up it can be recharged by forcing current through it. This reverses the chemical action. When the storage battery has been recharged, it can once again produce an * ______.

A-513

Since the zinc electrode loses only positive charges, the plate itself becomes ______ charged.

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A-497

Batteries produce current by changing chemical energy into electrical energy. The electric current produced by a battery depends on the [ ] activity in the battery.

A-517

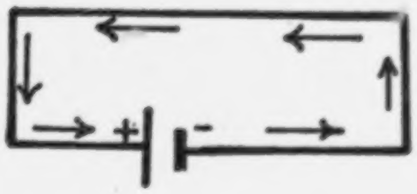
If two electrodes were connected by a conductor, electrons would flow from the negative electrode to the positive electrode. This flow of charge is known as an [*].

A-537

If different materials are used to make the cells of a dry battery, different voltages can be produced. However, most of the dry cells we use produce a potential difference of [*].

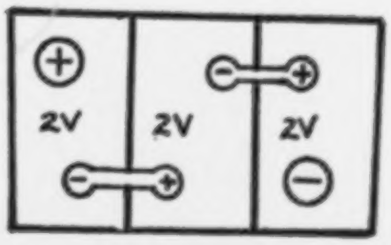
A-557

The path current takes as it goes from the [ ] terminal to the [*] is called a circuit. The figure is a diagram indicating the path of current. This type of diagram is known as a [ ] diagram.



A-577

When cells are connected in series, the anode of one is connected to the cathode of the next. The figure shows three 2 v cells in [ ]. The total potential difference is [#].



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END OF UNIT

---

a-572

sum
6.0 v.

---

a-552

difference of potential (or voltage)
2.0

---

a-532

electrodes
electrolyte

---

a-512

attract

A·I·R ©1960

a-497

chemical

a-517

electric current

a-537

1.5 volts

a-557

negative
positive terminal
circuit

a-577

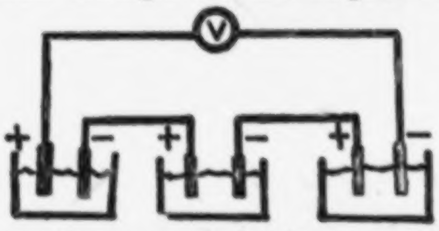
series
6.0 v (Your answer is not correct unless you indicate the unit of measurement, in this case, volts or v.)

A·I·R ©1960

END OF UNIT

A-572

To find the voltmeter reading in this diagram, we find the sum of the voltages for each cell. The ________ of the cell voltages in this figure is 6.0 v. The voltmeter will read # ______ volts.

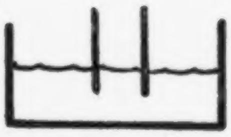


A-552

The chemical action in dry batteries produces a * ________ of about 1.5 volts for each single cell. A single cell in a storage battery by chemical action produces about # ______ v.

A-532

The most common kind of storage battery uses plates of lead and lead dioxide as the ________, and dilute sulphuric acid as the ________.



A-512

When a zinc plate is placed in acid, the negatively charged SO_4 ions from the acid electrolyte attract positively charged zinc ions. This is because unlike charges ________ each other.

A·I·R ©1960

A-498

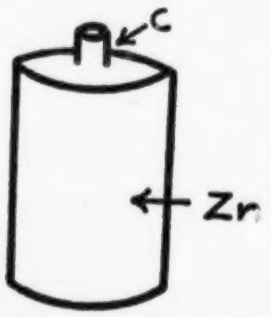
A battery converts chemical energy into [ ] energy. A [ ] is a source of electrical energy.

A-518

The point at which the conductor is connected to the negative electrode is called the negative terminal. The point at which the conductor is connected to the positive electrode is called the [*].

A-538

The figure shows a dry cell, the outer container is zinc (Zn), the rod in the center is carbon (C). The anode is made of [ ] and the cathode is made of [ ]. The potential difference of this cell is [#] volts.

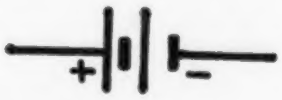


A-558

The path which current takes as it flows from a negative terminal to a positive terminal is called a [ ]. A diagram indicating the path of current is called a [ ] diagram.

A-578

This is a diagram of two cells in series. If each of the cells have a voltage of 1.5 v, the total voltage would be [#].



A·I·R ©1960

a-591

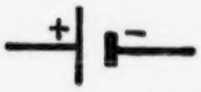
anode
negative
cathode
cathode
anode

A-571

4.0 v.

a-551

anode
cathode



a-531

electrical energy
chemical energy

a-511

charged
ions

A·I·R ©1960

a-498

electrical
battery

a-518

positive terminal

a-538

carbon
zinc
1.5

a-558

circuit
circuit

a-578

3.0 v

A·I·R ©1960

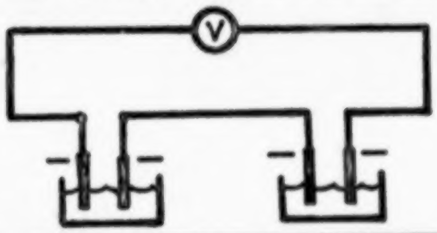
A-591

One electrode in a cell has a positive charge and is called the [ ]. The other electrode has a [ ] charge and is called the [ ]. Current flows from the [ ] to the [ ].

A-571

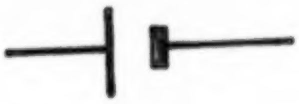
A battery usually consists of more than one cell. If we have two cells, and attach the anode of one to the cathode of the other, we find the voltage between the remaining anode and cathode is the sum of the two cell voltages.

In the figure, the voltmeter would read 2 v, plus 2 v, or a total of [#] volts.



A-551

In the figure, the long thin line indicates the [ ]. The short heavy line indicates the [ ]. Label the terminals in the figure using "+" and "-".



A-531

The wet battery used in automobiles is called a storage battery. A storage battery converts chemical energy into [*], but it can also convert electrical energy back into [*]. For this reason, it can be discharged and recharged many times.

A-511

Sulphuric acid will become ionized when it is mixed with water. Ionization is the chemical process in which a molecule breaks up into [ ] particles or fragments. Portions of the metal plates are "dissolved" by the acid and also break up into charged particules known as [ ].

A·I·R ©1960

A-499

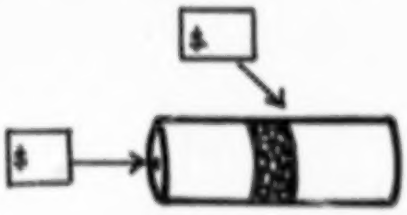
Batteries consist of one or more units called cells. A cell is a complete unit. A battery might be made up of only one ☐ or of many ☐.

A-519

Physicists call the positive electrode the anode. In a voltaic cell carbon rod becomes positively charged. Therefore, the carbon rod is the ☐.

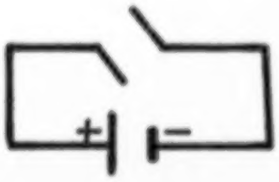
A-539

Here is a flashlight battery. It is a dry cell and produces a potential difference of ☐ # volts. Label the anode with a "+" and the cathode with a "-".



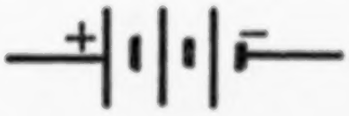
A-559

An open circuit means that the path is broken at some point. Current will not flow. In the figure, the conductor has been broken; this is therefore a diagram of an ☐ * ☐.



A-579

The figure shows ☐ # cells in ☐. If the action of each cell produces a voltage of 2 v, the total potential difference would be ☐ #.



A·I·R ©1960

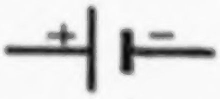
a-590

anode (cathode)
cathode (anode)
circuit

a-570

2.0
2.0

a-550



a-530

voltaic cell
electrolyte

a-510

ionization
ion

A·I·R ©1960

a-499

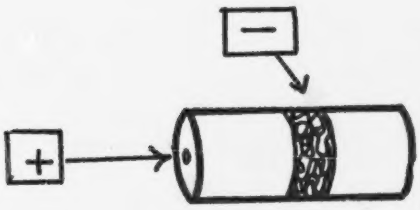
cell
cells

a-519

anode

a-539

1.5



a-559

open circuit

a-579

3
series
6.0 v

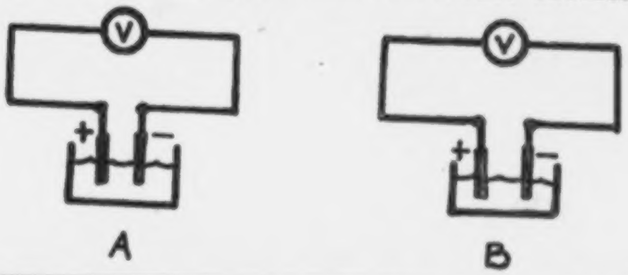
A·I·R ©1960

A-590

In order to establish a flow of current we need a source providing a difference of potential, and a conductor which is connected to the [ ] and the [ ] of the source, or battery, thereby forming a [ ].

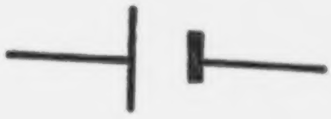
A-570

This figure shows two storage cells. The potential difference between the anode and the cathode of A is [#] volts; and between the anode and cathode of B is [#] volts.



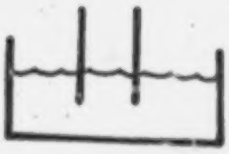
A-550

Using a "+" and "-" identify the anode and the cathode.



A-530

The other kind of battery used today is the wet battery. The wet battery contains a liquid electrolyte. The earliest kind of cell, a [*] contained a liquid [ ].



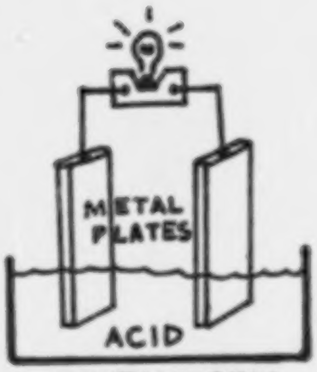
A-510

A common electrolyte is dilute sulphuric acid. Chemists call it H_2SO_4 (say, H-2, S-0-4). When [ ] occurs, the molecules of sulphuric acid break up into three charged particules, two positively charged H ions and one negatively charged SO_4 [ ].

A·I·R ©1960

A-500

Volta discovered that two kinds of metal placed in acid and connected by a conductor will produce an electric current in the conductor. The type of cell based on Volta's work is called a voltaic (say, vol-tay-ic) cell. Most batteries are modern versions of the ________.



VOLTAIC CELL

A-520

The negative electrode is called the cathode. The carbon rod is the ________, the zinc plate in a voltaic cell is the ________.

A-540

One electrode is positive. It is called the ________. The other electrode is negative. It is called the ________. The plates in a storage cell or the carbon core and zinc shell in a dry cell, are all called ________.

A-560

A closed circuit is continuous from the cathode to the anode; it is unbroken. Current (will/will not) ________ flow in a closed circuit.

A-580

Dry cells usually have a voltage of 1.5 v. Three dry cells in series would give a total of ________ volts.

A·I·R ©1960

a-589

cathode

a-569

circuit
2.0

a-549

positive
negative

a-529

dry

a-509

ionization

250

A·I·R ©1960

a-500

voltaic cell

a-520

anode
cathode

a-540

anode
cathode
electrodes

a-560

will

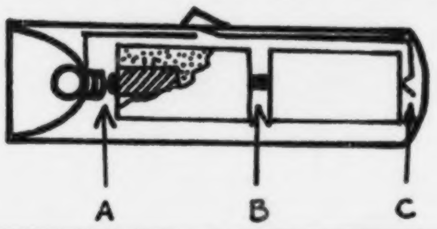
a-580

4.5

A·I·R ©1960

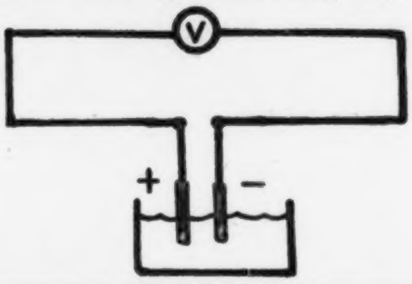
A-589

A flashlight also has cells in series. The diagram shows the circuit used for a flashlight. The anode of one cell is connected to the ☐ of the other at point B.



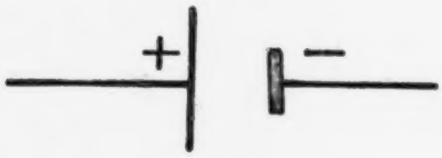
A-569

The figure shows a storage cell. A ☐ has been made by connecting the cathode and the anode to a voltmeter with a conductor. The voltmeter in the circuit will indicate a potential difference of ☐ # volts.



A-549

The figure shows the symbol for a battery. The long thin line always represents the anode or ☐ terminal and the short thick line always represents the cathode or ☐ terminal.



A-529

Dry batteries will produce current until the chemical energy is used up. Then they must be replaced. Flashlight batteries, for instance, must be replaced when the energy is used up. Flashlight batteries are ☐ batteries.

A-509

Ions are charged fragments of molecules. When they break up, due to chemical activity, this is known as ☐.

A·I·R ©1960

A-501

Most batteries are based on the principles discovered by Volta. The type of cell he devised is known as a [*].

A-521

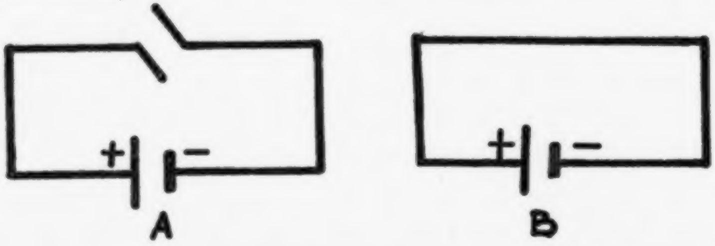
The positive terminal, like the positive plate, is called the [ ]. The negative terminal, like the negative plate, is called the [ ].

A-541

Most storage cells have a potential difference of about 2 volts. In a storage cell, the [ ] are made of lead and lead dioxide and the [ ] is dilute sulphuric acid.

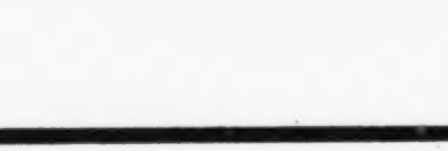
A-561

In the figure, A is a diagram of an [ ] circuit. B is a diagram of a [ ] circuit. Current will only flow in circuit [$].



A-581

Dry cells normally have a voltage of [*]. A diagram of several dry cells in series is shown. The total potential difference is [*].



A·I·R ©1960

a-588

3
3
A (and) F

a-568

circuit

a-548

difference of potential
terminal
anode

a-528

electrolyte
electrodes

a-508

ions

A·I·R ©1960

a-501

voltaic cell

a-521

anode
cathode

a-541

electrodes (or, plates)
electrolyte

a-561

open
closed
B

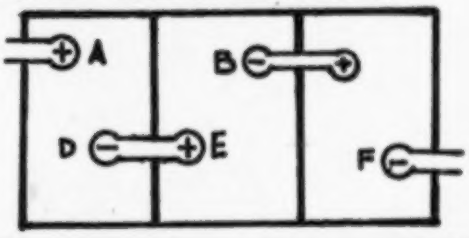
a-581

1.5 volts
6.0 volts

A·I·R ©1960

A-588

The figure shows a 6 v storage battery similar to the one in many cars. It has # ____ anodes, and # ____ cathodes. To obtain 6 volts, we must connect our circuit to the terminals labeled $ ____ and $ ____.



A-568

When a connection is made between the cathode and anode, a path is established for the current to follow. In other words, a ________ has been made.

A-548

To create a current we must have a difference of potential. In a battery there is a * ________ between the negative terminal and the positive ________; that is, between the cathode and the ________.

A-528

A dry cell consists of a paste, a zinc container and a carbon rod. The paste is the ________ and the zinc and carbon rod are the ________.

A-508

The process of ionization is the breaking up of molecules into charged fragments called ________.

A·I·R ©1960

A-502

The diluted acid (acid mixed with water) in a cell is called the electrolyte (say, e-lek-tro-lite). One type of voltaic cell contains dilute sulphuric acid. The dilute sulphuric acid is used as an [ ].

A-522

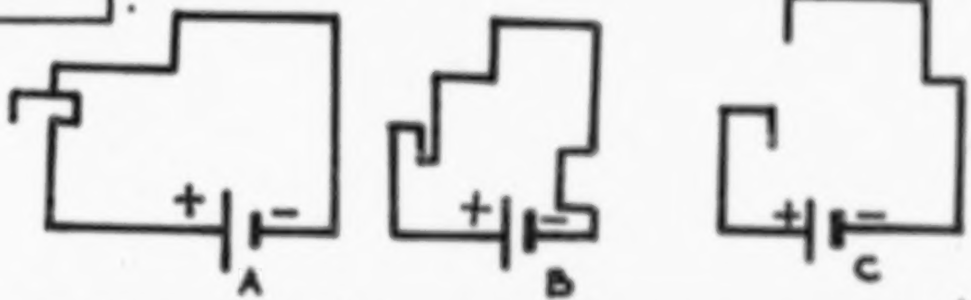
Since the [ ] has a positive charge, it has [ ] potential with respect to ground. The [ ] has a negative potential with respect to ground.

A-542

The materials used in making a storage cell produces a potential difference of [#] volts.

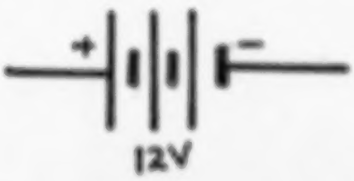
A-562

In the figure, A is a diagram of a [ ] circuit, B of a [•] and C of an [•].



A-582

If there are several cells in a battery, only a few are usually shown in a diagram of the battery, and the total voltage is written underneath. The diagram shows a battery having a total voltage of [#] volts. Even though the diagram does not show it, this battery actually consists of [#] 2 v. cells connected in series.



A·I·R ©1960

a-587

2
2
series

a-567

1.5

a-547

voltage

a-527

electrolyte

a-507

electrolyte

A-I-R ©1960

㉙

a-502

electrolyte

---

a-522

anode
positive
cathode

---

a-542

2 (or, about 2)

---

a-562

closed
closed circuit
open circuit

---

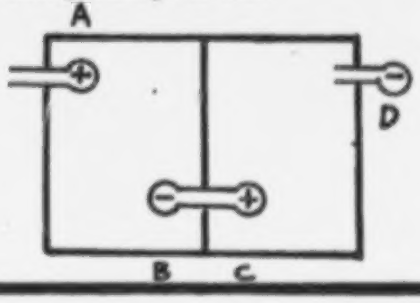
a-582

12
6

A·I·R ©1960

A-587

The figure is a diagram of a 4 volt storage battery. Altogether, it has [#] anodes and [#] cathodes. To obtain 4 volts we make a circuit using terminals A and D. This battery consists of two cells connected in [ ].



A-567

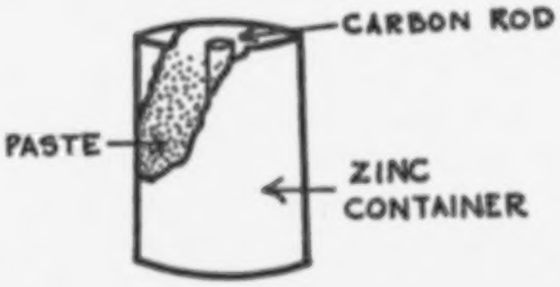
A dry cell has a potential difference of [#] volts. A storage cell has a potential difference of 2.0 volts.

A-547

The size of a cell does not affect the voltage. A large cell can produce more current than a small cell, but the [ ] will remain the same.

A-527

Dry batteries are used in flashlights and portable radios. A dry battery consists of a zinc container, has a carbon rod in the center, and is filled with a paste. The zinc and the carbon rods are the electrodes and the paste is the [ ].



A-507

When sulphuric acid is mixed with water to form the [ ] of a cell, the molecules break up into two or more charged fragments called ions.

A·I·R ©1960

A-503

The voltaic cell contains a dilute acid which is called the ☐.

A-523

In a cell, the source of positive charge is called the ☐ and the source of negative charge is called the ☐.

A-543

The size of the cell will have no effect on the potential difference. Only the materials used will affect the ☐ * produced by a particular kind of cell.

A-563

A switch is the name of the device we use to open and close circuits. When the switch allows current to flow we say the circuit is ☐.

A-583

To get a large potential difference using batteries, we can ☐ ** ☐. This will give us a potential difference equal to the ☐ ** ☐.

A·I·R ©1960

a-586

3
6

a-566

1.5
1.5

a-546

electric current

a-526

voltaic

a-506

voltaic cell
electrolyte
electrodes

A·I·R ©1960

a-503

electrolyte

a-523

anode
cathode

a-543

potential difference

a-563

closed

a-583

connect several cells in series
sum of the cell voltages

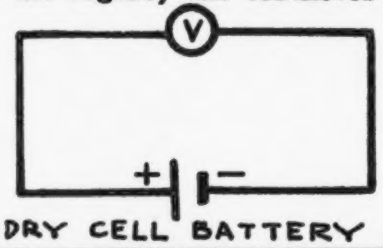
A·I·R ©1960

A-586

Most automobiles use either a 6 v or a 12 v storage battery. Since we know each cell in a storage battery produces about 2.0 v, the 6 v battery has # cells in series. The 12 v battery has # cells in series.

A-566

A dry cell has a potential difference of about # volts. The symbol for a voltmeter is V. In the figure, the voltmeter will indicate # volts.



A-546

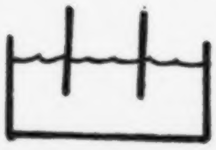
In order to have a continuous electrical current, there must be a continuous supply of charge at one end of a conductor and a means of escape for the charge at the other end. Otherwise the flow of electrons or * will stop.

A-526

There are two main kinds of batteries used today, dry batteries and wet batteries. Both kinds are based on the same principle as the ☐ cell.

A-506

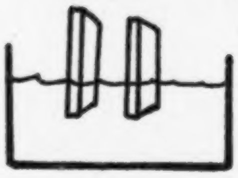
Volta devised a type of cell known as a * which contains dilute acid called the ☐ and two metal plates called the ☐.



A·I·R ©1960

A-504

A cell also contains two kinds of conductors, usually metal plates, for instance, zinc and carbon. The plates are called electrodes. (say e-lek-trodes). A cell contains two plates called ________ and dilute acid called the ________.



A-524

The acid used in a voltaic cell is known as the ________. The plates are known as ________.

A-544

A larger cell can provide more current, but the * ________ will not be increased by using a larger cell.

A-564

The switch on the wall opens and closes a ________. When the light is on, current is flowing so we know there is a ________ circuit. When the light is off, we know the circuit is ________.

A-584

Connecting cells in series will ** ________ ________.

A·I·R ©1960

a-585

voltmeter

a-565

switch
close

a-545

potential difference
current

a-525

positive
negative electrode

a-505

electrical

A·I·R ©1960

a-504

electrodes (you should be sure to spell these words correctly)
electrolyte

a-524

electrolyte
electrodes

a-544

potential difference (between the plates)

a-564

circuit
closed
open

a-584

produce a total voltage equal to the sum of the individual cell voltages

A·I·R ©1960

A-585

We can measure the total voltage of a battery by using an instrument called a __________.

A-565

A doorbell button also opens and closes a circuit. It is a kind of a __________. When we push the button, we __________ the circuit and the bell rings.

A-545

The size of a cell will not affect the * __________, but it will affect the amount of __________ that can be produced.

A-525

The anode is the __________ electrode. The cathode is the * __________.

A-505

A battery cell changes chemical energy into __________ energy.

A·I·R ©1960

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

PRECEDING PAGES MISSING

UNIT SIX

RESISTANCE AND RESISTORS

Steps A-592 through A-745

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

UNIT ENDS HERE

A-592

Every conductor offers some opposition to the current flowing through it. Physicists call this opposition resistance. Copper is usually used as a conductor because it has less ________ than many other metals such as lead and iron.

A-624

The potential difference measured between the terminals of a battery when current is flowing through a circuit is the * ________. The e.m.f. is always (greater than/less than) ________ the applied voltage.

A-656

The e.m.f. refers to the potential difference in an open circuit. The initials stand for * ________.

A-688

The resistance in a series circuit (is/is not) ________ the same for any portion of the circuit. The total resistance is equal to the ** ________.

A-720

The resistance produced by a wire is proportional to its ________. Decreasing the length of a wire, decreases its ________ proportionally.

A·I·R ©1960

a-719

B

a-687

is
at any point in the circuit.

a-655

6 volts

a-623

electromotive force
applied voltage

A·I·R ©1960

a-592

resistance

---

a-624

applied voltage
greater than

---

a-656

electromotive force

---

a-688

is not
sum of the individual resistances in the circuit

---

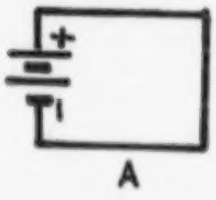
a-720

length
resistance

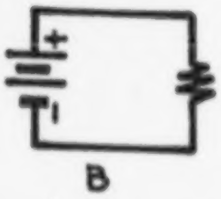
A·I·R ©1960

A-719

Actually, wires do have resistance but when we study circuits we assume there is no resistance in a circuit unless it is indicated by the symbol   In the figures, only circuit [$] is indicated as having resistance.



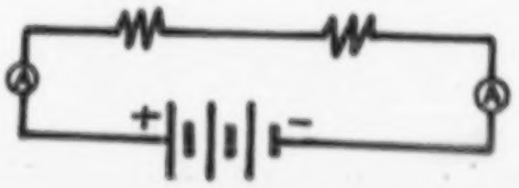
A



B

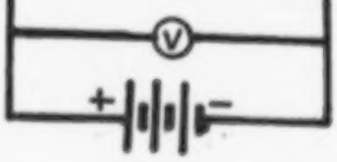
A-687

The current in a series circuit (is/is not) [ ] the same wherever it is measured. The total amount of current is equal to the amount of current measured [**].



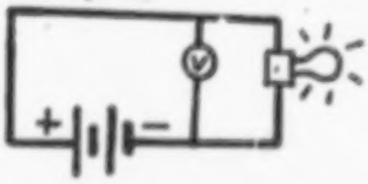
A-655

In the circuit below, which uses three cells of 2 v in series, the total electromotive force is [ ].



A-623

When we speak of the voltage of a circuit we mean the applied voltage not the [*]. In this circuit, the voltage represented by the voltmeter is an [*].



A·I·R ©1960

A-593

The opposition by a conductor to current flowing through it is called ☐. A good conductor produces little ☐; a poor conductor produces a large amount of ☐.

A-625

Ohm's Law shows the relationship between resistance, voltage, and ☐.

To find resistance, we use the formula R = ☐ $.

A-657

Within a battery there is internal resistance to current, therefore the voltage, before current is drawn, is always greater than voltage while current is flowing. In other words, the ☐ * is greater than the ☐ *.

A-689

The voltage across a series circuit (is/is not) ☐ the same for every portion of the circuit. The total applied voltage is the ☐ **.

A-721

Since the resistance of a wire is proportional to its length, half of the wire would have ☐ the total resistance, one-third of the wire would have ☐ of the total resistance of the wire.

A·I·R ©1960

a-718

half

---

a-686

2 amps. (or, the same)

---

a-654

electromotive force (or, e.m.f.)

---

a-622

applied voltage

a-593

resistance
resistance
resistance

a-625

current
(R=) $\frac{V}{I}$

a-657

electromotive force
applied voltage

a-689

is not
sum of the individual voltages across each part of the circuit

a-721

half
one-third

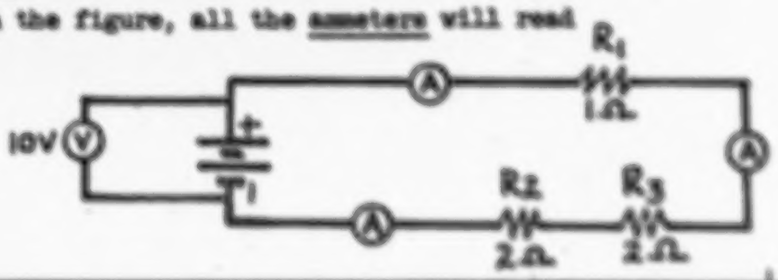
A·I·R © 1960

A-718

The resistance of a wire is proportional to the length of that wire. If the wire in the circuit is shortened to half its length, the wire would then have ______ the resistance.

A-686

In a closed series circuit, the current flowing through the circuit is the same no matter where in the circuit it is measured. In the figure, all the ammeters will read ______.



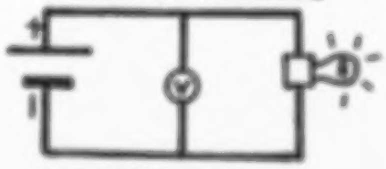
A-654

The voltage of a battery connected to an open circuit is called the * ______ ______. It is produced by chemical action in the battery.

A-622

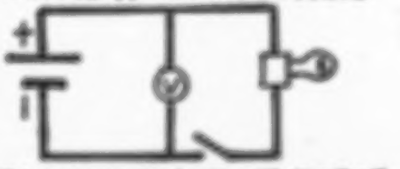
Actually, the voltage we get from a battery during use, when current is flowing, is less than the e.m.f. The voltage obtained when current is flowing is called the applied voltage. The * ______ is always less than the e.m.f.

CURRENT FLOWING



APPLIED VOLTAGE

CURRENT NOT FLOWING



ELECTROMOTIVE FORCE

A·I·R ©1960

A-594

Resistance is the opposition to current flowing through a conductor. A substance which has a high resistance will provide a large amount of ☐ to current flowing through it.

A-626

All materials produce some resistance to current. Usually, we do not consider the resistance produced by the wire used in connecting the circuit, but the wire nevertheless does have some ☐.

A-658

The drop in voltage produced by internal resistance is an example of what is sometimes called an IR drop. The term, IR drop, means a drop in voltage due to resistance as indicated by the Ohm's Law formula, V = ☐ $.

A-690

From Ohm's Law we know that every circuit is "balanced" mathematically; that is, the voltage equals the current times the ☐, or V = ☐ $. It is impossible to have a circuit which is not ☐ mathematically.

A-722

Resistance depends on the kind of material used, the thickness of the material, and the length of the material. For a given material, increasing the thickness decreases the resistance, but increasing the length ☐ the resistance.

A·I·R ©1960

a-717

wire
2

a-685

(V =) IR
$(R =) \frac{V}{I}$
$(I =) \frac{V}{R}$

a-653

current
current will flow

a-621

electromotive force

A-I-R ©1960

a-594

opposition

---

a-626

resistance

---

a-658

IR

---

a-690

resistances

(V =) IR

balanced

---

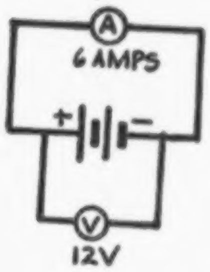
a-722

increases

A-I-R ©1960

A-717

This circuit has no special resistor in it, but we know there will be some resistances produced by the ______ in the circuit. The amount of resistance can be computed. In this case it is # ______ ohms.



A-685

The formula used to find voltage is, V = $ ______ , to find resistance is, R = $ ______ ; and to find current is, I = $ ______ .

A-653

When a circuit is open, no ______ will flow. When a circuit is closed, ** ______ .

A-621

The initials e.m.f. are the abbreviation for voltage measured when current is not flowing. E.m.f. stands for * ______ .

A·I·R ©1960

A-595

Resistance is the ________ to current flowing through a ________. No current is likely to flow through an insulator because it offers so much ________.

A-627

When we talk about the resistance in a circuit, we usually mean the resistance produced by a light bulb, an electric motor, or some other object or objects included in a ________. Resistance in a circuit is indicated with the symbol -^^^^-
The symbol $________ stands for some object in the circuit producing resistance.

A-659

There is also a drop in voltage that occurs when current flows through a resistor. This voltage drop is also called an $______ drop.

A-691

In every circuit, V must equal IR. If V is 12 volts, I is 3 amps and R is 4 ohms, multiplying I and R will give us the number #______. Since this is the same as the measured voltage of the circuit, we know the circuit is ________.

A-723

As the length of a material which produces resistance increases, the resistance ________. As the thickness of the material increases, the resistance ________.

a-716

resistance (to the flow of current)
resistance

a-684

(V =) IR
Kirchhoff's
voltages

a-652

resistance
less

a-620

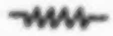
electromotive force
difference

A·I·R ©1960

a-595

opposition
conductor (or, circuit)
resistance

a-627

circuit


a-659

IR (drop)

a-691

12
balanced

a-723

increases
decreases

A·I·R ©1960

A-716

Copper is usually used to make electrical wires because it has a small resistance to the flow of current. For special purposes, silver is sometimes used as a conductor because it offers even less ________. All wires offer some ________.

A-684

To find the total voltage across a circuit, we can first add the resistances and then use Ohm's Law that V = $ ________, or we can find the voltage drop across each resistor and then, using the formula for ________ law, add the ________.

A-652

The current flowing in a circuit depends on the applied voltage and the amount of ________ in the circuit. The higher the resistance, the ________ is the amount of current that will flow.

A-620

The voltage measured across the terminals of a battery, when current is not flowing is called the e ________. This is the amount of potential ________ produced by the chemical action of the cells.

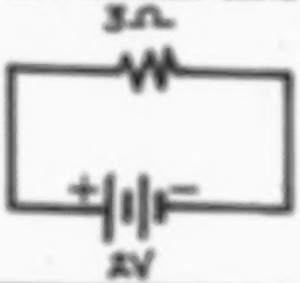
A·I·R ©1960

A-596

The amount of resistance depends on the kind of material through which the ______ is flowing. Resistance also depends on the length of the wires; that is, the length of the ______.

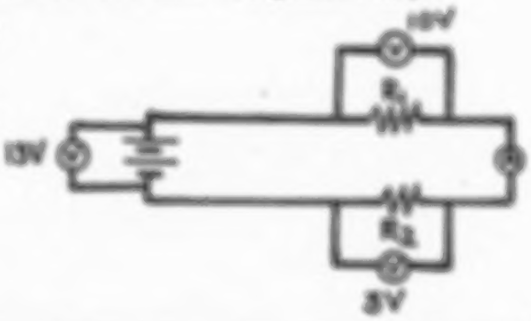
A-628

Resistance is shown in a diagram as a zigzag line —WWW—. The resistance shown in this circuit is given as # ohms.



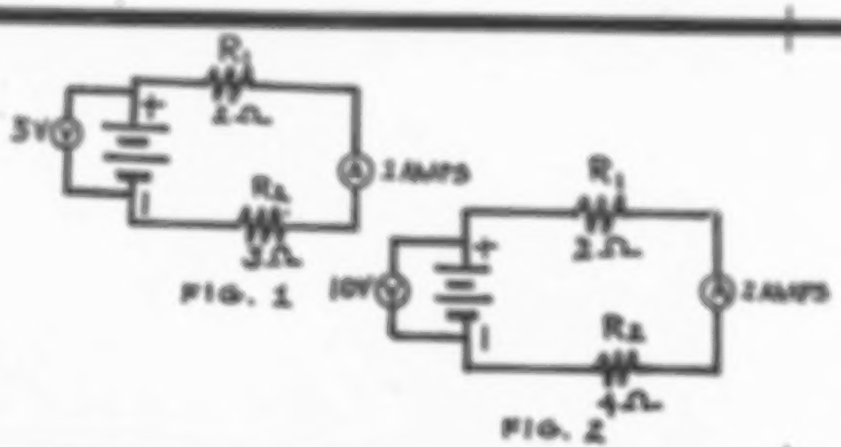
A-660

When we speak of voltage, we mean the difference of potential between two points or, as physicists say, "across" a resistor or portion of a circuit. In the figure, there is a potential difference of 10 v across R_1, a potential difference of 3 v ______ R_2, and a potential difference of 13 v ______ the entire circuit.



A-692

The circuit in Figure 1 (is/is not) ______ mathematically balanced. There (could/could never) ______ be a circuit like this. The circuit in Figure 2 (is/is not) ______ mathematically balanced. There (could/could never) ______ be a circuit like this.



A-724

A wire is made of a material of uniform thickness. A short piece of the wire will produce a ______ amount of resistance than a longer piece.

A·I·R ©1960

a-715

resistance (or, opposition)

a-683

Kirchhoff's
total applied voltage in series circuit is equal to the sum of voltages across each part of the circuit.

a-651

less
4 amps
2 amps

a-619

electromotive

A·I·R ©1960

a-596

current
conductor

a-628

3

a-660

across
across

a-692

is
could
is not
could never

a-724

smaller

A·I·R ©1960

A-715

So far, we have ignored the resistance produced by the wires themselves in a circuit. Every material, however, offers some ☐ to the flow of current.

A-683

Kirchhoff's law states that $V_T = V_1 + V_2 + V_3$ in a series circuit. In words, ☐ law is that the ☐ **

A-651

The greater the resistance in a circuit, the smaller the amount of current that will flow. In these circuits, as resistors are added, the amount of current becomes (greater/less) ☐. The current flowing in Fig. 1 is ☐, the current flowing in Fig. 2 is ☐.

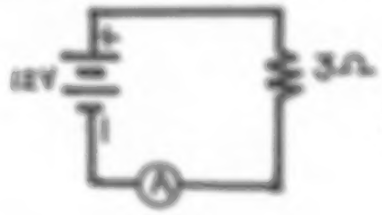


FIG.1

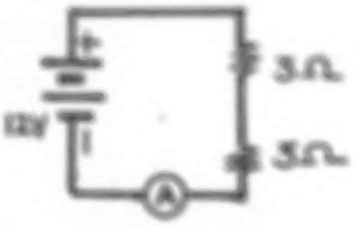
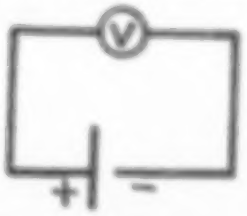


FIG.2

A-619

The potential difference across the terminals of a battery when current is not flowing is called the electromotive force. Attaching a voltmeter to the terminals of a battery will give us the potential difference produced by the chemical action of the cells called the ☐.



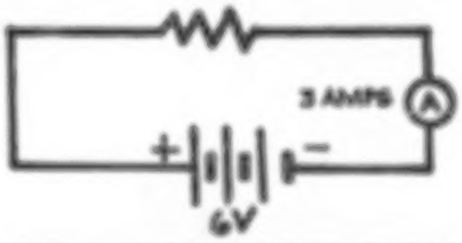
A·I·R ©1960

A-597

Any object which offers resistance to the flow of electric current is called a resistor. An electric toaster is an example of a ☐ because it offers ☐ to current flowing through it.

A-629

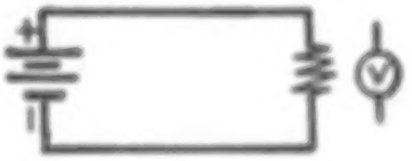
The figure shows a simple circuit. The battery supplies an applied voltage of 6 v. The ammeter indicated: Ⓐ, reads 3 amps. To find the resistance represented by the wavy line, we use the formula $R = \frac{V}{I}$. In this case, $R = \frac{6\ v}{3\ a}$ so R = 2 ohms.



3

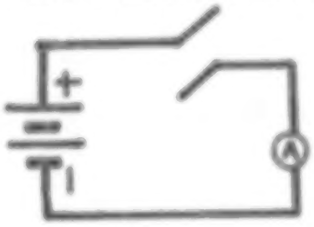
A-661

An IR drop is a drop in ☐ across a resistor as current flows through it. By "across" a resistor, we mean from one side of the resistor to the other. In the figure, draw wires to show how the voltmeter would be connected to measure the voltage across the resistor.



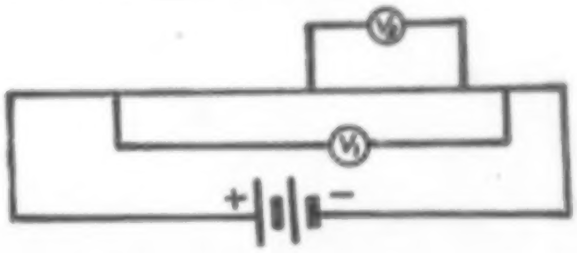
A-693

An ammeter measures the amount of current in a circuit. If a circuit is open, no current will flow; the ammeter will read zero. This circuit is (open/closed) ☐. The ammeter will read ☐.



A-725

For a material of uniform thickness, resistance is proportional to the length of the material and, as resistance increases, ☐ also increases. In this circuit, V_1 will read (more/less) ☐ voltage than V_2.



A·I·R ©1960

END OF UNIT

---

a-714

insert a resistor (or, increase the current)

---

a-682

6
24
8
16

---

a-650

12 v
4
2

---

a-618

flowing

A·I·R ©1960

a-597

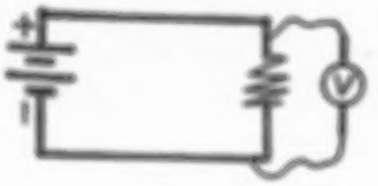
resistor
resistance (or, opposition)

a-629

2 (ohms)

a-661

voltage



a-693

open
zero

a-725

voltage
more

A·I·R ©1960

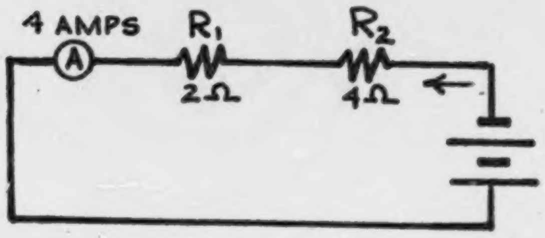
END OF UNIT

A-714

To increase the voltage between two points in a circuit we can **.

A-682

For this circuit, the total resistance is # ohms so the total voltage is # volts. The voltage across resistor R_1 is # volts and across R_2 is # volts.



A-650

These circuits both have a voltage of v. The current flowing through Fig. 1 is amps. The current flowing through Fig. 2 is amps.

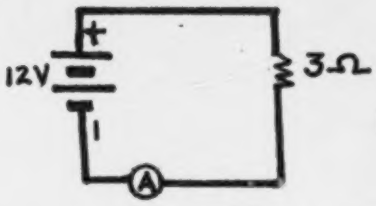


FIG. 1

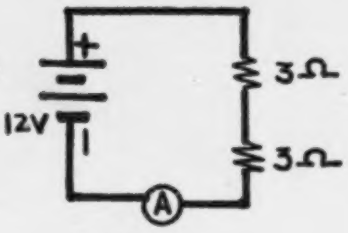


FIG. 2

A-618

Anytime current flows through a circuit, there is some resistance to it. When we measure electromotive force, we determine the potential difference between the terminals of a battery when current is not . To do this, we attach a voltmeter to the terminals of a cell. Practically no current actually flows through a voltmeter.

962

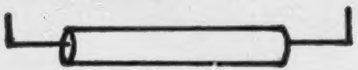
A·I·R ©1960

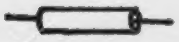
A-598

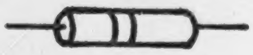
Materials offering resistance to the flow of current are called ________.

A-630

Sometimes, especially in radios and TV sets, we use objects made of a special kind of material to produce resistance. We call these objects, and all other objects which oppose the flow of current through them, resistors. Many radio and TV resistors look like small, solid cylinders with a wire coming out of each end. The drawings are of several ________ of the type used in radios.







A-662

Generally, in speaking of the voltage of a battery, we refer to the potential difference while current is being drawn, or the applied voltage. A 12 v battery generally means that the applied voltage and not the * ________ is 12 v.

A-694

The circuit in Figure 1 shows a flow of 6 amps of current. If we open the circuit, as in Figure 2, current will * ________, and the ammeter will read ________ amps.

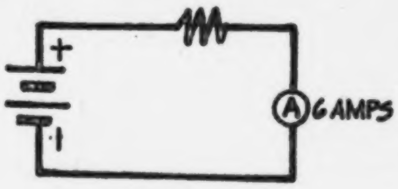


FIG. 1

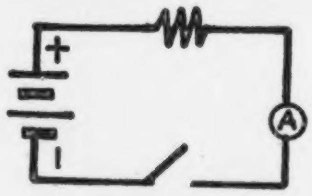


FIG. 2

A-726

For a given piece of material of uniform thickness, the voltage will be proportional to the length of the material so long as the current is constant. The voltmeter in Figure 1 will measure (more/less) ________ voltage than the voltmeter in Figure 2.

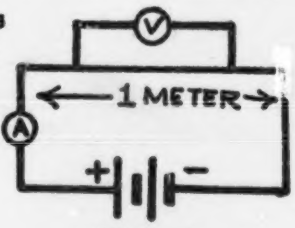


FIG. 1

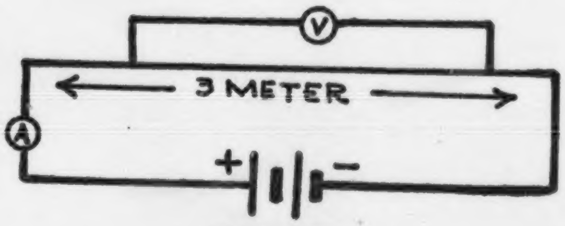


FIG. 2

A·I·R ©1960

a-745

current

a-713

resistor

a-681

15

a-649

(I =) $\frac{V}{R}$

a-617

electromotive force

A·I·R ©1960

(301)

a-598

resistors

---

a-630

resistors

---

a-662

electromotive force

---

a-694

no longer flow
zero

---

a-726

less

A·I·R ©1960

A-745

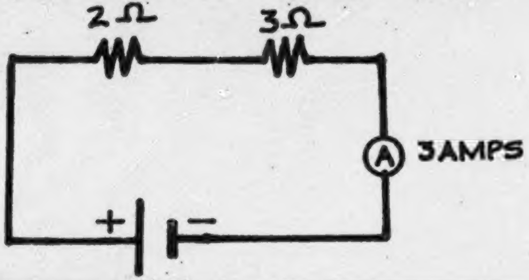
A variable resistor is used when there is a fixed source of voltage, as from a battery, and we want to obtain a variable amount of $\boxed{\qquad\qquad}$ by adjusting the resistance.

A-713

A resistor of the type used in radios is designed especially to produce resistance. To increase the potential difference between two points in a circuit, we can insert a $\boxed{\qquad\qquad}$.

A-681

In Ohm's Law, $V = IR$ and $R = R_1 + R_2$. Therefore, we find the total voltage being supplied to this circuit is $IR_1 + IR_2$, or $\boxed{\#}$ volts.



A-649

The voltage available in a circuit is usually known; we know if we have a 6 volt battery, a 12 volt battery, etc. More often, it is important to calculate the current in a circuit using Ohm's Law that I =

$\boxed{\$\quad}$.

A-617

If we want to measure the voltage between the terminals of a battery, we can attach a voltmeter to the terminals. The voltage measured across the terminals of a battery is called the electromotive force. Another name for the potential difference at a source is the $\boxed{*\qquad\qquad\qquad\qquad}$.

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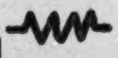
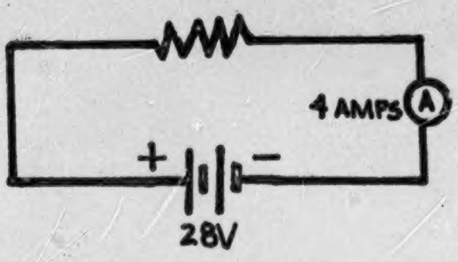
A-599

Resistance is the ** ______________________________
______________________.

A-631

Usually, we use the symbol  to mean an object in the circuit which produces resistance; that is, a __________.
There is a resistor in this circuit.
The resistance it produces is # ______
ohms.



A-663

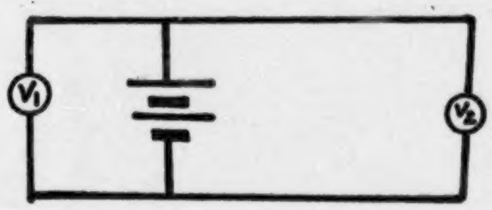
The potential difference across an entire circuit is called the applied voltage. Attaching a voltmeter to the battery terminals while current is flowing will give us the potential difference of the entire circuit, or the * ____________________.

A-695

According to Ohm's Law, the total resistance of a series circuit is equal to the sum of the ______________.

A-727

In this circuit, V_1 will read (more/less) ______ voltage than V_2.



A·I·R ©1960

a-744

4

---

a-712

(V =) IR

18

6

---

a-680

sum

140 v

---

a-648

20

20

---

a-616

$I = \frac{V}{R}$

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a-599

opposition by a conductor to current flowing through it

a-631

resistor
7 (ohms)

a-663

applied voltage

a-695

resistances

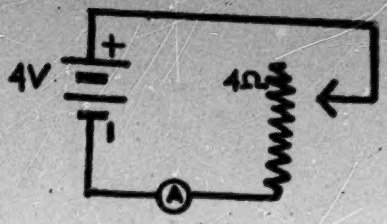
a-727

less

A·I·R ©1960

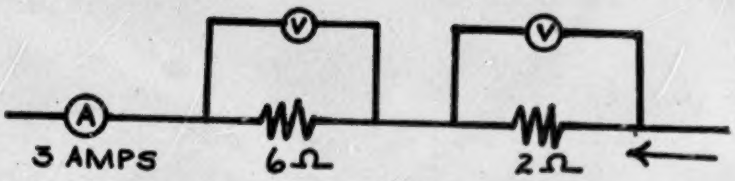
A-744

In this circuit, the variable resistor is 8 inches long and produces a maximum of 4 ohms. To obtain 2 amps, we would use # inches of the resistor.



A-712

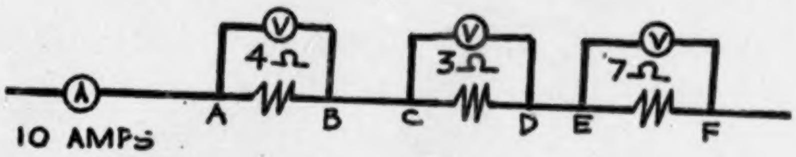
In this circuit, there are 3 amps of current flowing. The voltages across each resistor, using the formula V = $, will be different. The difference of potential across the 6 Ω resistor would be # volts, while the difference of potential across the 2 Ω resistor would be # volts.



A-680

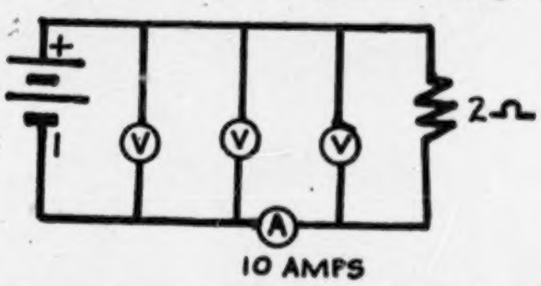
The total voltage across a series circuit is equal to the ☐ of the voltages across each of the resistors in the series.

The total voltage of this circuit is therefore ☐ as measured from A to F.



A-648

In the circuit below, there are three voltmeters. Since V = IR, the applied voltage of the circuit is # volts. All three voltmeters will indicate the circuit voltage. All three will read # volts.



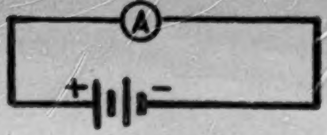
A-616

To find current when resistance and voltage are known, the formula is $.

A·I·R ©1960

A-600

G. S. Ohm found that, for a given circuit, current was always proportional to the voltage. Using the circuit below, for instance, he found a 2 volt battery produced 10 amps; a 4 volt battery, 20 amps; and a 6 volt battery, * __________.



A-632

If we have two batteries in series, this means the __________ flows first through one and then through the other. If we have two resistors in series the __________ will flow first through one and then ** __________.

A-664

The potential difference at a source, such as a battery when current is not flowing, is called the __________ force. The potential difference across the entire circuit is called the __________ voltage.

A-696

$V = IR_1 + IR_2$ means that voltage equals current times ** __________ __________.

A-728

In these identical circuits, voltmeters have been connected to the wires in two different ways. Since the length of wire enclosed by the voltmeter is the same in each figure, (from A to B,) the __________ indicated by the voltmeters will be the same in both cases.

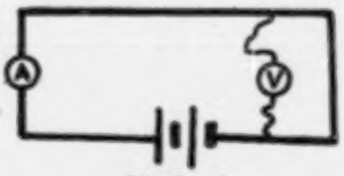


FIG. 1

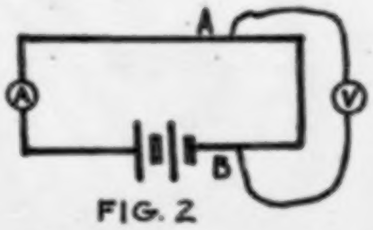


FIG. 2

A·I·R ©1960

a-743

2

1

(R =) $\frac{V}{I}$

a-711

resistance

a-679

4 v

10 v

14 v

a-647

40 v

a-615

V = IR

A·I·R ©1960

a-600

30 amps

---

a-632

current
current
through the other

---

a-664

electromotive
applied

---

a-696

the first resistor plus current times the second resistor

---

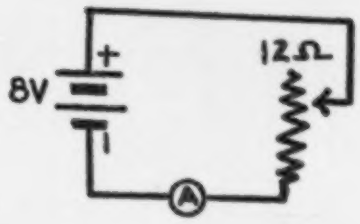
a-728

voltages

A·I·R ©1960

A-743

In this circuit the variable resistor is six inches long and produces a maximum of 12 ohms. In other words, one inch produces [#] ohms. To obtain 4 amps, we would use [#] inches of the resistor. Use the formula R = [$] to find the amount of resistance needed.

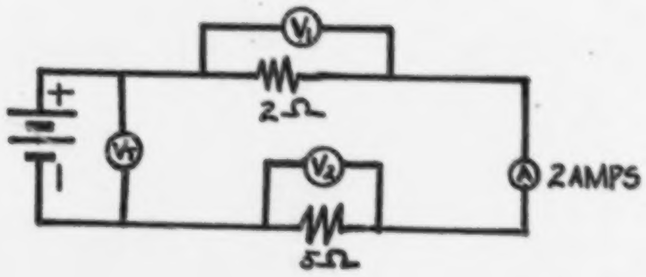


A-711

If the amount of current is constant, the voltage will depend on the [ ] in the circuit.

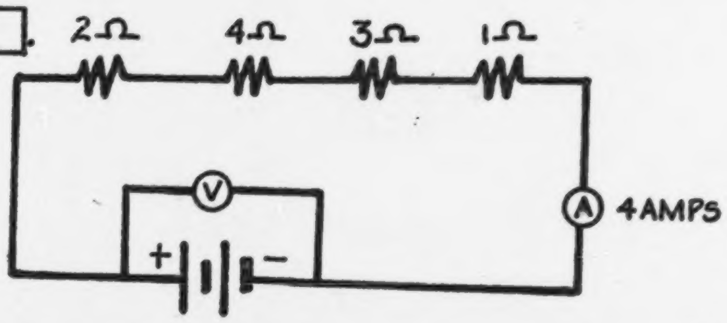
A-679

In this circuit, V_1 will read [ ], V_2 will read [ ], and V_T will read [ ].



A-647

The applied voltage in this circuit is [ ].



A-615

The equation for using Ohm's Law to find voltage when resistance and current are known is [$].

A·i·R ©1960

A-601

Ohm found that as voltage increases, the amount of [ ], measured in amps, also increases. To obtain an increase in current, we can increase the [ ].

A-633

When resistors are connected in series the total resistance of the circuit is the sum of the individual resistances, or, total $R = R_1 + R_2 + R_3$. If three resistors in series in a circuit have resistances of 5Ω, 10Ω, and 2Ω, the total resistance of the circuit is [#].

A-665

When we measure the voltage of a battery at rest (Figure 1) we are measuring the voltage available at the source, that is, the [ ] force. When we measure the voltage of a battery in a closed circuit (Figure 2), we are measuring the [ ] voltage.

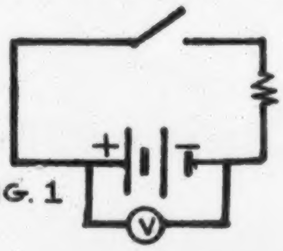


FIG. 1

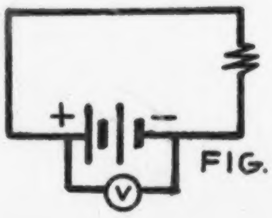


FIG. 2

A-697

The electromotive force of a battery is always greater than the applied voltage. The battery voltage measured in an [ ] circuit is always greater than a [ ] circuit.

A-729

The resistance of a material is proportional to the length of the material. If we double the length of the wire, the resistance will be [ ].

A·I·R ©1960

a-742

2

a-710

20
60

a-678

the sum of the voltages (voltage drops) for each portion (or, $V = V_1 + V_2 + V_3$)

a-646

$V = IR$
50 v

a-614

$R = \frac{V}{I}$

A·I·R ©1960

a-601

current

voltage

a-633

17 Ω

a-665

electromotive

applied

a-697

open

closed

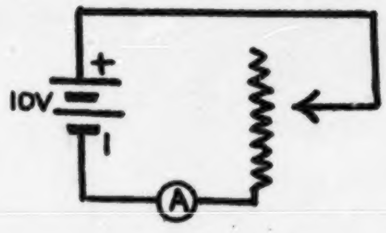
a-729

doubled

A·I·R ©1960

A-742

The circuit shows a 10 volt source, a variable resistor and an ammeter. The amount of resistance which must be produced by the resistor to make the ammeter read 5 amps is # ohms.



A-710

In Figure 1, the voltmeter will read # volts. In Figure 2, it will read # volts. Because resistance is the opposition to current, the voltage between any two points depends on the resistance between those two points.

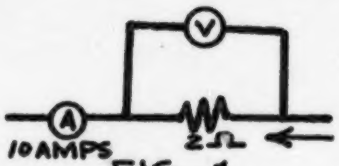


FIG. 1

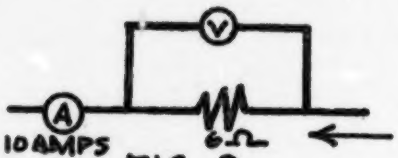


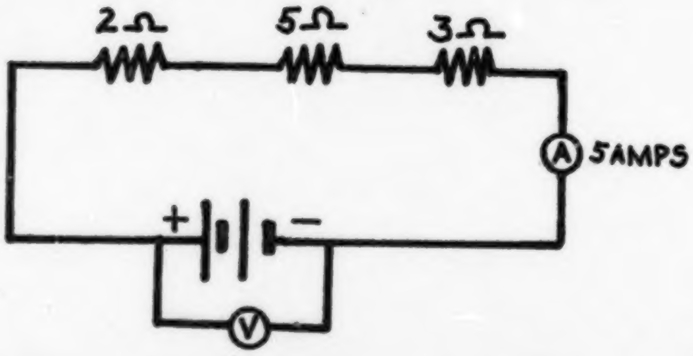
FIG. 2

A-678

The total voltage in a series circuit according to Kirchhof's Law is equal to ** .

A-646

The Ohm's Law formula for finding voltage when I and R are known is V = $. The applied voltage in this circuit is .



A-614

The equation or formula for using Ohm's Law to find the resistance in a circuit is $.

A·I·R ©1960

A-602

Ohm found that for a given battery, the amount of current that would flow through a circuit of given length depended, in part, on the material used to make the circuit. In other words, he found that when a constant voltage was applied to several circuits, the current in each circuit depended on the ☐ offered by the material used in the circuit.

A-634

If the resistances of each of the resistors in series are known and the current is known, we can find the applied voltage of the circuit by using the equation V = IR. In this case, R means the total ☐ of the resistors in the series circuit.

A-666

The difference in size between electromotive force and applied voltage is due to the internal resistance in the battery. We can find the ☐ resistance in the battery by subtracting the applied voltage from the e.m.f. and dividing the answer by the current when applied voltage is being measured. We use the formula $R = \frac{V_{e.m.f.} - V_{a.v.}}{I}$ to find the ☐ in the battery.

A-698

The electromotive force of a battery is always ☐ than the applied voltage.

A-730

In these figures, the ohms refer to the resistance of the wire. In Figure 1, the voltmeter will read # volts.
In Figure 2, using half the wire, we have decreased the resistance to # ohms. Providing we kept the current the same, the voltmeter in Figure 2 would read # volts.

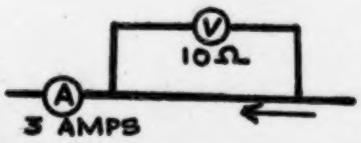


FIG. 1

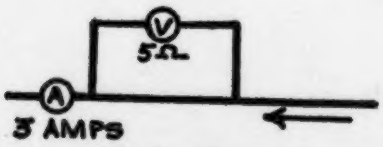


FIG. 2

A·I·R ©1960

a-741

fixed amount of resistance
length

a-709

difference of potential
X (and) Y
2
10
20

a-677

resistance
sum

a-645

decrease

a-613

resistance
voltage
current

A·I·R ©1960

③⑰

a-602

resistance (or, opposition)

a-634

resistance

a-666

internal
internal resistance

a-698

greater

a-730

30
5
15

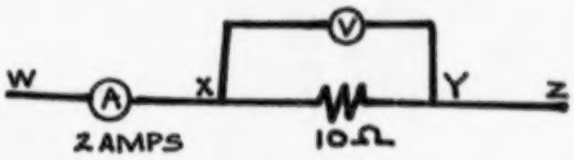
A·I·R ©1960

A-741

A fixed resistor produces a ** ______. The kind of material, its thickness, and also its ______ are generally constant.

A-709

In this circuit the voltmeter shows the * ______ between points $ ______ and $ ______. The ammeter tells us # ______ amps of current are flowing through the # ______ ohm resistor. The voltmeter must therefore indicate a difference of potential of # ______ volts.



A-677

Difference of potential measured in a series circuit, depends on the amount of ______ between any two points. The total voltage in a series circuit is found the same way as the total resistance in a series circuit. The total voltage is equal to the ______ of the voltages in the circuit.

A-645

If we have only a 6 volt battery available, and increase the amount of resistance, we will ______ the amount of current flowing through the circuit.

A-613

Ohm's Law can be stated in three ways, as $R = \frac{V}{I}$ to find ______, as $V = IR$ to find ______, and $I = \frac{V}{R}$ to find ______.

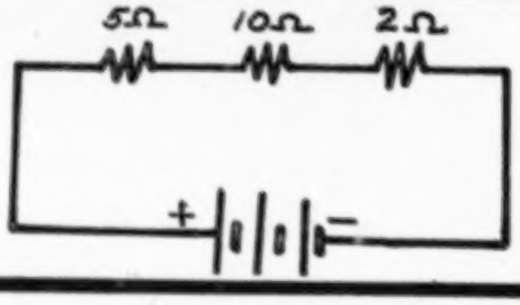
A·I·R ©1960

A-603

Ohm defined resistance in terms of what he had discovered. Resistance is equal to voltage divided by current. Using R for resistance, V for voltage and I for current, the formula is $R = \frac{\boxed{\#}}{\boxed{\#}}$.

A-635

The total resistance in a series circuit is equal to the ☐ of the ☐. The total resistance in this series circuit is $\boxed{\#}$.



A-667

To find the amount of internal resistance, we need to know the electromotive force, which is the voltage at the battery measured when the circuit is ☐. We also need to know the applied voltage, which is the voltage at the battery measured $\boxed{**}$. The difference between the two voltages, divided by the current flowing through the closed circuit will indicate the $\boxed{*}$ of the battery.

A-699

Since e.m.f. is always greater than the applied voltage, we know there must be some cause for a drop in voltage inside the battery when current is flowing. Resistance causes a drop in voltage when current is flowing, so the difference between e.m.f. and applied voltage must be due to resistance within the battery or $\boxed{*}$.

A-731

A resistor is a special material which is designed to produce opposition to the flow of ☐. The amount of resistance produced by a material depends on the kind of material, the thickness of material, and the ☐ of material.

A·I·R ©1960

a-740

resistance can be changed (or, adjusted)
length
kind (width)
width (kind)

a-708

50
50

a-676

27 v

a-644

(I =) $\frac{V}{R}$
2 amps
1 amp

a-612

3 amps

A·I·R ©1960

a-603

(R =) $\frac{V}{I}$

a-635

sum (or, total)
resistances
17

a-667

open
when the circuit is closed (or, when current if flowing)
internal resistance

a-699

internal resistance

a-731

current
length

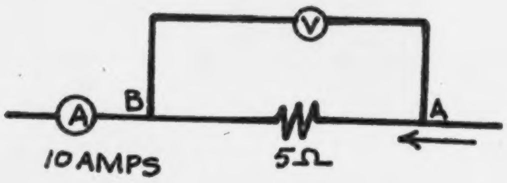
A·I·R ©1960

A-740

A variable resistor is one in which ** ________ by adjusting its ________. The ________ of material and ________ of material used are generally constant for the entire length of the resistor.

A-708

A voltmeter indicates the difference of potential between the ends of a resistor, that is, from point A to point B. Since the ammeter tells us 10 amps of current are flowing through this 5 Ω resistor, there must be a difference of potential of # ________ volts. Therefore the voltmeter will read # ________ volts.



A-676

Kirchhoff (pronounced Kir-kof) found that the voltage applied to a series circuit is equal to the sum of the drops in potential differences across each of the resistors in that circuit, or, $V_T + V_1 + V_2 + V_3$. If the potential differences produced by each of three resistors in series circuit are 12 v, 10 v, and 5 v, the total voltage is ________.

A-644

Increasing the resistance in a circuit decreases the amount of current for any given battery. Since I = $ ________, we can compute current. In these circuits, the current in Figure 1 is ________. In Figure 2, the current is ________.

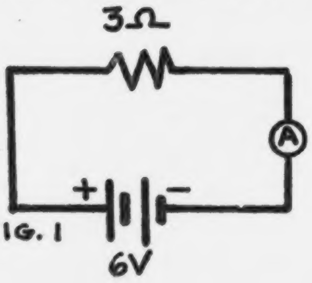


FIG. 1

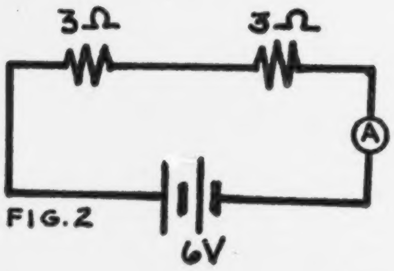


FIG. 2

A-612

Since $I = \frac{V}{R}$, when the voltage is 110 v and resistance is 11 Ω, the current will be 10 amps. When voltage is 12 v and resistance is 4 Ω, the current will be ________.

A·I·R ©1960

A-604

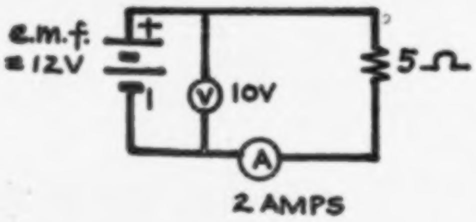
The formula, resistance equals voltage divided by current is known as Ohm's Law. Using symbols, another way of stating [ ] Law is $R = \frac{V}{I}$.

A-636

The total resistance of resistors in series is equal to [**].

A-668

The e.m.f. of the battery in the figure is 12v. To find the amount of internal resistance, we subtract the [ ] voltage from the e.m.f., or 12 v minus [#] v leaves [#] v. Then, we divide this difference by the amount of current or [#] amps. This indicates an internal resistance of [#] ohm.



A-700

The voltage drop across a resistor is known as the IR drop. Using Ohm's Law, V = IR, we can find the voltage drop or [ ] across a resistor.

A-732

Resistance of material depends on the kind of material, thickness of material and [ ] of material. By kind of material we mean copper, iron, etc. Copper offers less [ ] than iron.

A·I·R ©1960

a-739

kind of the material, the thickness of the material, and the length of the material

---

a-707

(V =) IR

6

6

---

a-675

6 v

12 v

---

a-643

(V =) IR

20 v

10 v

---

a-611

Ohm's

I (= $\frac{V}{R}$)

A·I·R ©1960

a-604

Ohm's

a-636

sum of the resistances of all ths resistors

a-668

applied
10
2
2
1

a-700

IR drop

a-732

length
resistance

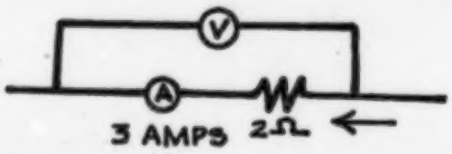
A·I·R ©1960

A-739

The resistance, in ohms, produced by a resistor depends primarily on three things. These are the [**].

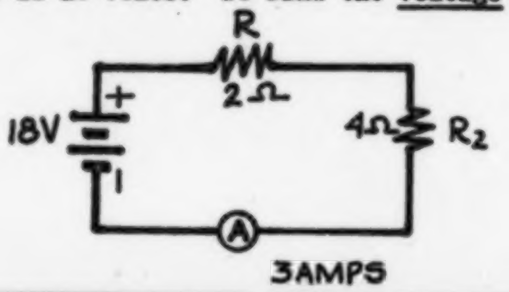
A-707

In order to find the amount of voltage required to force current through a resistor, we use the formula V = [$]. To force 3 amps through a 2 Ω resistor requires [#] volts. In the figure, we are using a 2 Ω resistor and know 3 amps are being forced through. The voltmeter would read [#] volts.



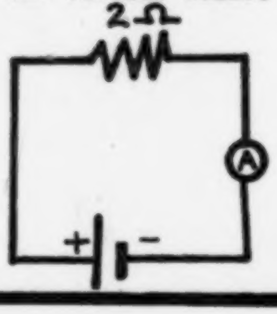
A-675

In the circuit below, the total voltage is 18 volts. To find the voltage drop, across each resistor Ohm's Law, V = IR, is used. In this circuit, the voltage drop across R_1 is [ ]. The voltage drop across R_2 is [ ].



A-643

Suppose we wanted to have 10 amps flowing through the circuit below. By using Ohm's Law to find volts, V = [$], we know that to do this we would need a [#] volt battery in the circuit. If we only wanted 5 amps, we would only need a [#] volt battery.



A-611

Knowing the resistance and voltage of a circuit, the current can be calculated by dividing voltage by resistance. This is still another way of stating [ ] Law. In symbols it would be [$] = $\frac{V}{R}$.

A·I·R ©1960

A-605

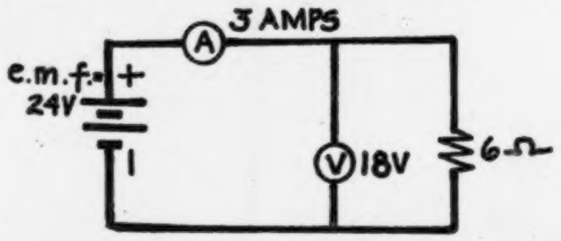
Current is measured in units called [ ]. The unit of resistance is called an ohm. The formula $R = \frac{V}{I}$ can therefore be written in terms of units of measure as $\text{ohms} = \frac{[\#]}{[\#]}$

A-637

All the current will pass through each part of the circuit in turn if it is a [ ] circuit.

A-669

The e.m.f. of the battery in this figure is [#] v. The applied voltage is [#] v. The difference in voltage between them is [#] v. Using Ohm's Law formula that $R = \frac{V\text{ e.m.f.} - V\text{ a.v.}}{I}$, the internal resistance in this battery is [#] ohms.



A-701

The drop in voltage across a resistor is known as an [*].

A-733

A fixed resistor is made to provide a specified resistance. The amount of resistance produced by a fixed resistor depends on the [ ], [ ], and [ ] of the material.

A·I·R ©1960

a-738

8

---

a-706

16
8
in half

---

a-674

Ohm's
(V =) IR

---

a-642

voltage

---

a-610

110 v

A·I·R ©1960

a-605

amperes (or, amps)
volts
amperes

a-637

series

a-669

24
18
6
2

a-701

IR drop

a-733

kind
thickness
length

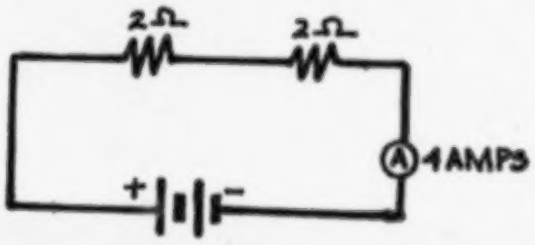
A·I·R ©1960

A-738

If a variable resistor 8 inches long has a maximum resistance of 16 ohms, and we use 4 inches of it, we will have [#] ohms resistance.

A-706

It would take [#] volts to force 4 amps through this circuit. Part of the voltage is required to overcome the resistance of each resistor. If there was only one 2 ohm resistor in the circuit, it would require only [#] volts to force 4 amps through the circuit. If the resistance is divided in half, the voltage required to produce the same current through the circuit is divided [*].



A-674

To find the potential difference across a resistor we use the form of [ ] Law, V = [$].

A-642

Resistance is the opposition by a material to the flow of current through it. Voltage is the amount of force available to move a current through a circuit. The greater the resistance in a circuit, the more [ ] will be required to move a given amount of current through a circuit.

A-610

A circuit has a resistance of 4 Ω and the current is 3 amps. Since V = IR, 4 Ω x 3 amps = 12 v. If a circuit has a resistance of 11 Ω and the current is 10 amps, the difference of potential is [ ].

OEC
A·I·R ©1960

A-606

The Greek letter "Omega" is used to designate ohms. The letter omega is written like this: Ω , If the resistance of a circuit is written in symbols as 4 Ω , it means that the resistance is four ________.

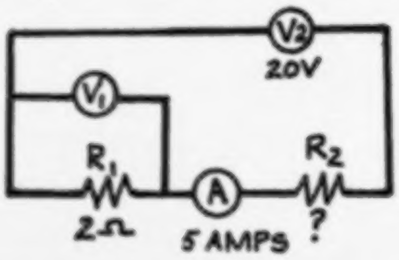
A-638

The formula for using Ohm's Law to determine current when voltage and resistance are known is I = $ ________. The total resistance, R, in the circuit, is the sum of the resistors in series ($R_1 + R_2 + R_3$, etc.). Thus, the formula can also be given as $I = \frac{V}{R_1 + R_2, \text{ etc.}}$

In words, this means ** ____
________________________.

A-670

When there are two resistors in series, and we know the value for one of them, we can find the value for the other. In this circuit, for instance, we know that $R = \frac{V}{I}$, so the total R is $\frac{20}{5}$ or 4 ohms. Since R_1 is 2 ohms, R_2 must be # ________ ohms.



A-702

To find the voltage drop or IR drop across each resistor we use the formula $ ________.

A-734

A variable resistor is made so that the resistance can be easily adjusted. Since it would be difficult to change the kind of material or thickness of material, we adjust the resistance of a variable resistor by changing the ________ of the material used.

a-737

5

a-705

of the individual resistances
16 (volts)

a-673

V = IR

a-641

2 (amps)

a-609

voltage equals current times resistance (or, volts equals amps times ohms)

A·I·R ©1960

a-606

ohms

a-638

$(I =) \frac{V}{R}$

current equals voltage divided by the sum of resistances in a series circuit

a-670

2

a-702

$V = IR$

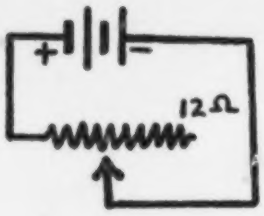
a-734

length

A·I·R ©1960

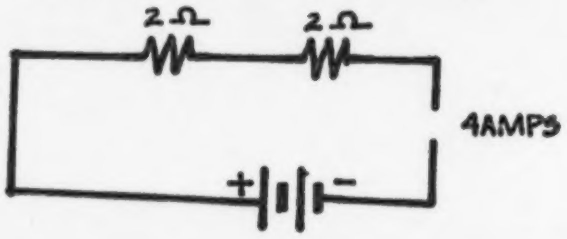
A-737

A variable resistor is indicated in the diagram. Usually the maximum resistance for the particular resistor is indicated. In the figure, the resistance produced in this case will be [#] ohms.



A-705

In this circuit, there are two resistors in series. The total resistance in the circuit is equal to the sum [**]. A potential difference of [#] volts would be required to force 4 amps of current through the circuit.

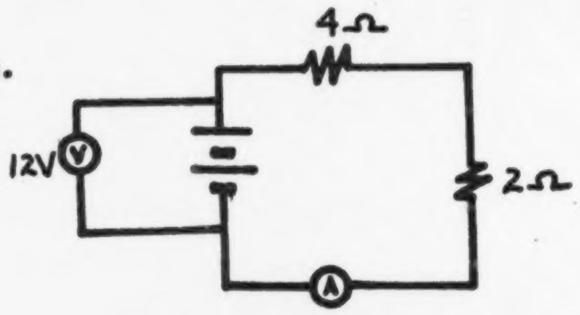


A-673

The total applied voltage of a circuit is almost always known. We choose a 2 volt battery, a 12 volt battery, etc. In general, the formula V = IR is used to find the voltage across a particular part of the circuit. To find the voltage across a particular resistor we use the formula [$].

A-641

In this circuit, the ammeter will read [#] amps.



A-609

The formula V = IR means, in words, that [**].

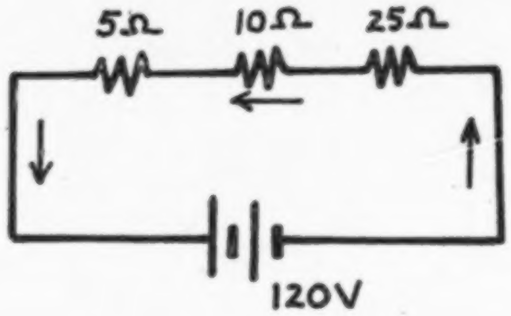
A·I·R ©1960

A-607

We can use the formula $\frac{V}{I} = R$ to determine the resistance in a circuit. If the voltage applied to a circuit is 110 volts and the current in the circuit is 10 amperes, the resistance of that circuit is 11 ohms: $\frac{110\ v}{10\ amps} = 11\ \Omega$. If the voltage is 12 volts, and the current is 3 amps, R is $\boxed{\ast\qquad}$.

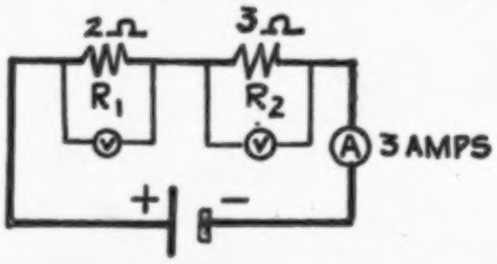
A-639

The voltage and the resistances are given for this series circuit. Find the current, that is, the amount of current. $I = \boxed{\#\quad}$ amps.



A-671

Since V = IR, for a given current, the voltage across each resistor will depend on the size of that resistor. In the circuit below, the voltage across R_1 is 6 volts. The voltage across R_2 is $\boxed{}$.

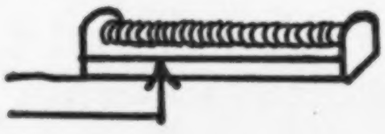


A-703

Kirchhoff's Law is that the total applied voltage in a series circuit is equal to the $\boxed{}$ of the voltages measured across each portion of the circuit. Another way of stating $\boxed{}$ Law is $V_T = V_1 + V_2 + V_3$.

A-735

A common type of variable resistor is shown in the figure. To obtain maximum resistance from this resistor, we use the entire $\boxed{}$ of it. To obtain less resistance, the slide can be moved so that the circuit includes less of the resistor.



A·I·R ©1960

a-736

5 ohms

a-704

sum of the voltages measured across each of the resistors (or, each portion of the circuit)
Kirchhoff's

a-672

(V =) IR
voltage
greater

a-640

2 amps

a-608

$R = \frac{V}{I}$
Ohm's

A·I·R ©1960

a-607

4 Ω (or, 4 ohms)

a-639

3 (amps)

a-671

9 volts

a-703

sum
Kirchhoff's

a-735

length

A·I·R ©1960

A-736

In Figure A, a variable resistor is shown. The position of the arrow indicates that the entire resistance of 10 ohms is being used. In Figure B, only half of the resistor is being used. Resistance of the circuit will be ________.

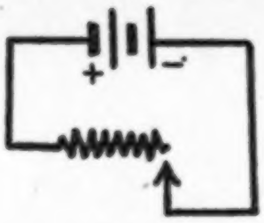


FIG. A

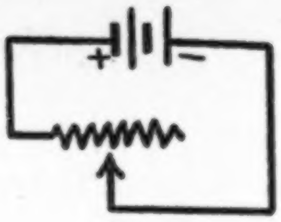


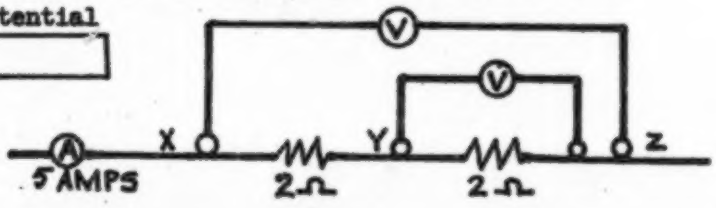
FIG B

A-704

The total applied voltage of a series circuit is equal to ** ________________________________. This is known as ________ Law.

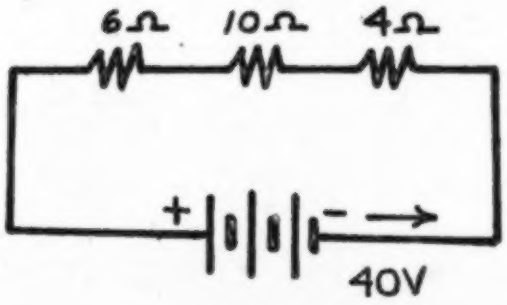
A-672

As stated by Ohm's Law, V = $ ________. This means that for a given current, the ________ between any two points will be proportional to the resistance between those points. We know, then, that the difference of potential between point X and Z must be (greater/less) ________ than that between points Y and Z.



A-640

The current in this circuit is * ________.



A-608

We have shown that if you know I and V, R can be found by the formula $ ________

By algebra, we can change the formula to V = I x R. This is another way of stating ________ Law.

A·I·R ©1960

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UNIT SEVEN

POTENTIAL DIVIDER AND WHEATSTONE BRIDGE

Steps A-746 through A-868

Special Instructions

This Unit contains a number of arithemetic problems. Try each one. You will find it is easy to do even the long problems if you work carefully on each problem as it comes up. Do not try to do too many questions at one time. Relax for a while after each few problems and they will seem easier. If you have not already done so, it may be a good idea to go through the Special Mathematics Section in the Introductory booklet.

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

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TURN BOOK AROUND AND CONTINUE HERE

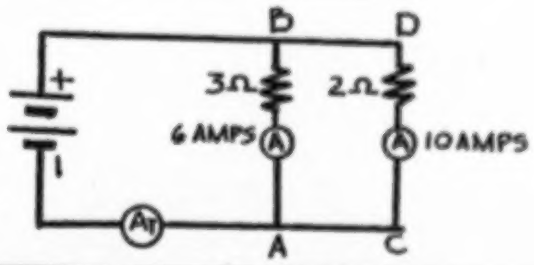
UNIT ENDS HERE

A-746

Most voltage sources are constant. When the voltage supply is constant, we can vary the current by adjusting the ☐ in the circuit. One way to do this is to put a ☐ resistor into the circuit and adjust its length.

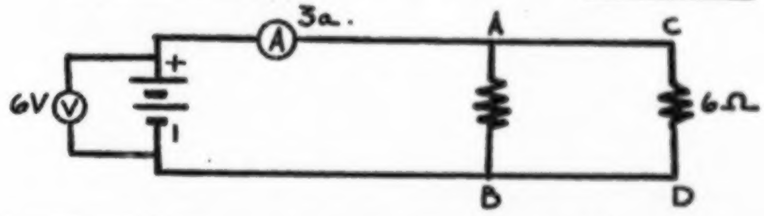
A-772

To find the voltage across each branch of a parallel circuit, we can use ☐ Law, V = IR. The voltage across each branch is the same as the voltage across the entire circuit. If the applied voltage is 12 v, the voltage in each branch will be # volts.



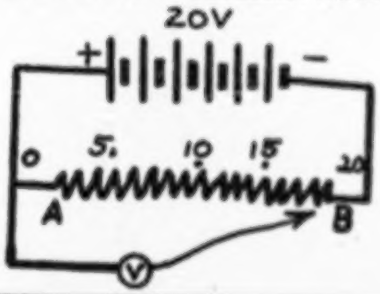
A-798

Find the current through each branch in this circuit, using the formula $I = \frac{V}{R}$. In branch AB, I = * and in branch CD, I = * .



A-824

A potential divider is an electrical circuit constructed around a variable resistor, or "rheostat" (say, ree-o-stat), with one sliding contact. From a zero voltage reading at A, we could increase the voltage reading steadily. At B, the voltmeter measures the potential difference across the entire circuit, so it would read # volts.



A-850

In algebra, if the same term appears both in a numerator and denominator, we can "cancel" or remove them. In the formula $\frac{I_1 R_{AC}}{I_1 R_{CB}} = \frac{I_2 R_{ED}}{I_2 R_{DF}}$, we can cancel all the "I's" and get $\frac{R_{AC}}{R_{CB}} = \frac{\boxed{\$}}{\boxed{\$}}$.

A·I·R ©1960

a-849

divide

$\frac{I_2 R_{ED}}{I_2 R_{DF}}$

a-823

resistor

resistor

galvanometer

a-797

12 ohms

10 amps

a-771

sum of the voltage drops (or, voltages) of each part

sum of the current in each branch

A·I·R ©1960

㉟

a-746

resistance

variable

---

a-772

Ohm's

12

---

a-798

2 amps

1 amp

---

a-824

20

---

a-850

R_{ED}

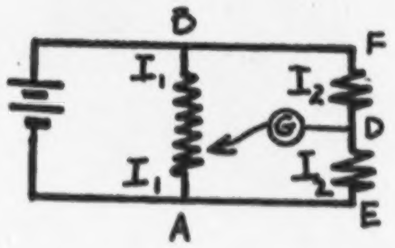
R_{DF}

A·I·R ©1960

A-849

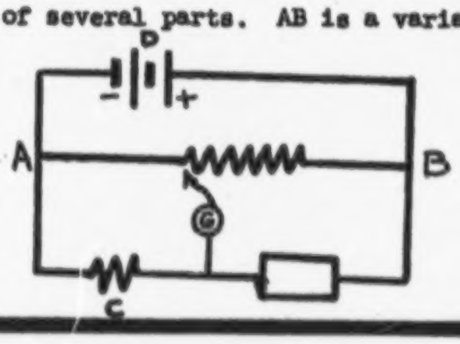
The Wheatstone Bridge circuit formulas are $I_1 R_{AC} = I_2 R_{ED}$ and $I_1 R_{CB} = I_2 R_{DF}$. We can [ ] one by the other; that is, $\frac{I_1 R_{AC}}{I_1 R_{CB}}$ =

$\frac{[\ \$\ ]}{[\ \$\ ]}$.



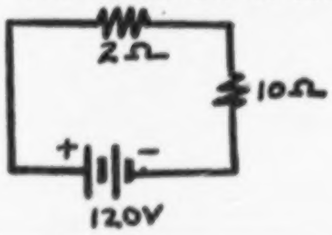
A-823

As shown in the figure, Wheatstone Bridge consists of several parts. AB is a variable [ ]. C is another [ ]. A battery is used as a power source, and an instrument called a galvanometer is also used. The part labeled Ⓖ is the [ ].



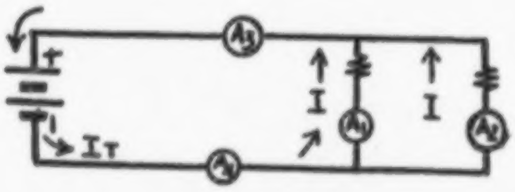
A-797

The diagram can now be simplified since we know the three resistors in parallel have an equivalent resistance of 2 ohms. The total resistance of the circuit can now be found. It is [*]. Since $I = \frac{V}{R}$, the total current in this circuit is $\frac{120}{12}$, or [*].



A-771

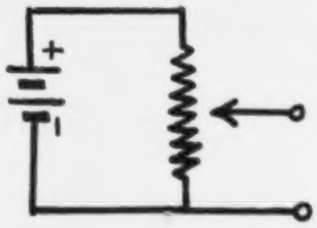
Earlier you learned Kirchhoff's Second Law, $V_T = V_1 + V_2 + V_3$, that the total voltage applied to a series circuit was equal to the [**].
Kirchhoff's First Law is that the total current in a parallel circuit is equal to the [**].



A·I·R ©1960

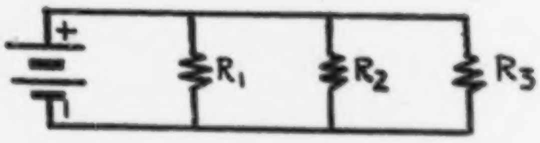
A-747

Sometimes, we want to adjust voltage rather than current. To do this, we use a device called a potential divider. As shown in the diagram, a * is similar to a variable resistor.



A-773

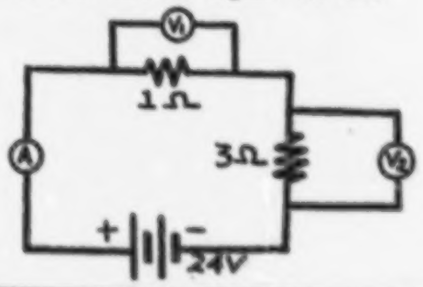
Each branch of a parallel circuit can be treated as a simple series circuit. In this circuit, the difference in potential, or IR drop, across each branch can be found using Ohm's Law, V = IR. For branch AB, V = # and for branch CD, V = #. The total current measured by A_T is # amps.



A-799

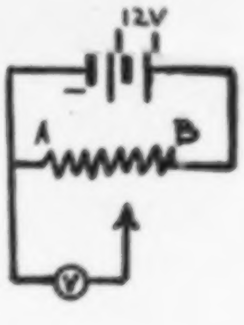
In a series circuit, the applied voltage across the entire circuit is equal to the **.

In this circuit, I = # amps, so V_1 will read ____ volts and V_2 will read ____ volts.



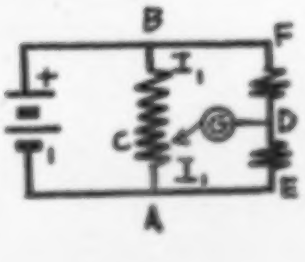
A-825

Part of the Wheatstone Bridge consists of a potential divider which, as you remember, is similar to a variable resistor. A potential divider is shown in the figure. When the slider is at B, the voltmeter will read # volts. When it is at A, it will read # volts.



A-851

Look at the figure, and then finish this equation: $\frac{R_{AC}}{\#} = \frac{\#}{\#}$.



A·I·R ©1960

a-848

d

divided by another

a-822

galvanometer

a-796

$(\frac{1}{R_E} =)\ \frac{6}{12}$

$(R_E =)\ 2$ (or, $\frac{12}{6}$)

a-770

current

current

a-747

potential divider

a-773

18

18

15

a-799

sum of the voltage drops (or, voltages) for each portion

6 (a)

18 (v)

6 (v)

a-825

12

0

a-851

$$\frac{R_{AC}}{R_{CB}} = \frac{R_{ED}}{R_{DF}}$$

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A-848

In algebra, one equation can be divided by another. This means if a = b and c = d, we can also say $\frac{a}{c} = \frac{b}{d}$. We know this is true because we can substitute a for b and c for $\boxed{\$}$. If we did, $\frac{a}{c} = \frac{a}{c}$, and we proved that one equation can be $\boxed{*\qquad\qquad\qquad}$.

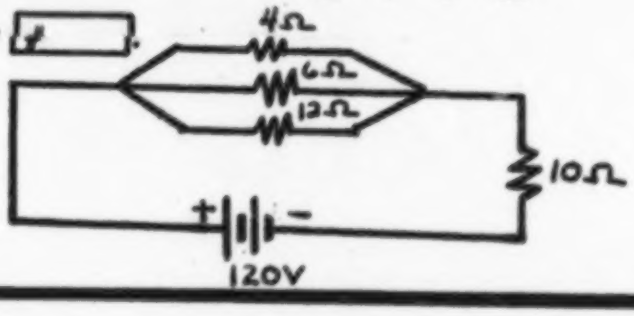
A-822

A galvanometer is a very sensitive instrument for indicating flow of current. It is very similar to an ammeter. We use an ammeter to measure a large current, but a $\boxed{\qquad\qquad}$ to measure very small amounts of current.

A-796

We first find the equivalent resistance of the parallel resistors. $\frac{1}{R_E} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$.

The common denominator is 12, so $\frac{1}{R_E} = \frac{\boxed{\#}}{\boxed{\#}}$ *and* $R_E = \boxed{\#}$.



A-770

Kirchhoff found that $I_T = I_1 + I_2 + I_3$ or, that the total $\boxed{\qquad\qquad}$ in a parallel circuit is equal to the sum of the $\boxed{\qquad\qquad}$ in the parallel branches. This is known as Kirchhoff's First Law.

A·I·R ©1960

A-748

Fig. 1 shows a * ______ . Fig. 2 shows a * ______ .

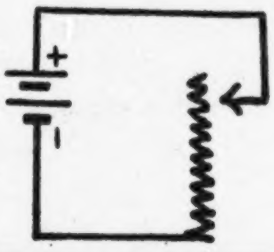


FIG.1

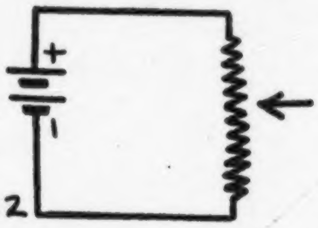


FIG.2

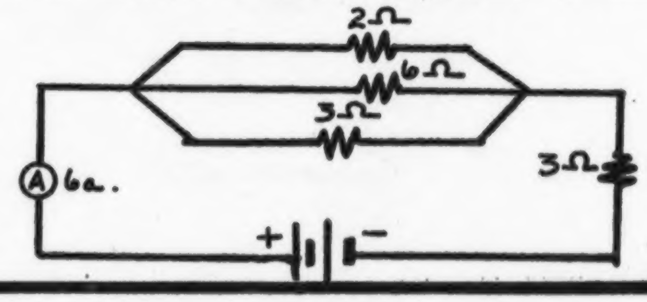
A-774

Ohm's Law can be stated in three ways, V = $ ______ , R = $ ______ , and

I = $ ______ .

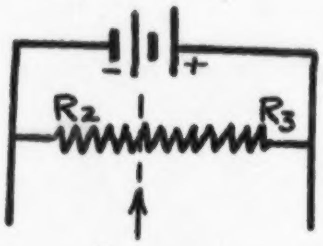
A-800

To find the current through each branch of a parallel circuit, it is first necessary to find the voltage across that portion if the circuit includes resistors in series. In this circuit, R_E for the parallel portion is # ______ ohms and the potential difference across the parallel portion is # ______ volts.



A-826

In the figure, the whole resistor represents 12 ohms. If R_2 is one third of it and R_3 is two thirds of it, R_2 represents # ______ ohms and R_3 represents # ______ ohms. These resistors form a ______ circuit since all the current flows through both of them.



A-852

Again using algebra, we can write the formula $\frac{R_{AC}}{R_{CB}} = \frac{R_{ED}}{R_{DF}}$ as $R_{DF}\frac{R_{AC}}{R_{CB}} = R_{ED}$. Using this formula, if R_{DF} were 3 ohms, R_{AC} were 8 ohms, and R_{CB} were 4 ohms, R_{ED} would be $3\ (\frac{8}{4})$ or 3 x 2, or 6 ohms. If R_{DF} were 2 ohms, R_{AC} were 12 ohms, and R_{CB} were 3 ohms, then R_{ED} would be * ______ .

A·I·R ©1960

a-847

$I_2 R_{ED}$

$I_2 R_{DF}$

a-821

resistance of an unknown material (or, unknown resistance)

a-795

resistance

a-769

the same

passes through each part of the circuit

branch

A·I·R ©1960

a-748

variable resistor
potential divider

a-774

$V = IR$

$R = \frac{V}{I}$

$I = \frac{V}{R}$

a-800

1 (ohm)
6 (volts)

a-826

4
8
series

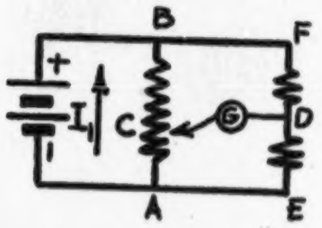
a-852

8 ohms

A·I·R ©1960

A-847

In a Wheatstone Bridge circuit, when the galvanometer reads zero, $I_1\ R_{AC}$ = [$], and $I_1\ R_{CB}$ = [$].

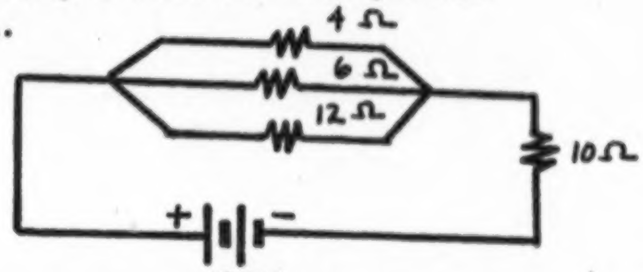


A-821

The peculiar name "Wheatstone Bridge" comes from the name of the man who invented the circuit used, and the fact that part of the circuit is "bridged" by a galvanometer. (Say, gal-van-om'-et-er) A Wheatstone Bridge is used to measure the [**].

A-795

To find the total current in this circuit, we first find the equivalent [ ] of the resistors in parallel.



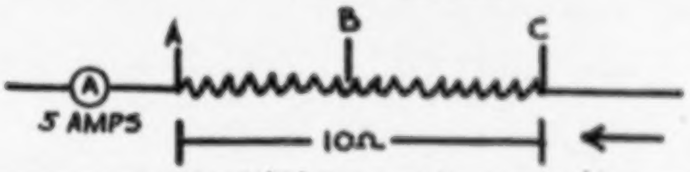
A-769

In a series circuit all ammeters would read [*] since all the current flowing through the circuit [**].
In a parallel circuit only part of the current flows through each [ ].

A·I·R ©1960

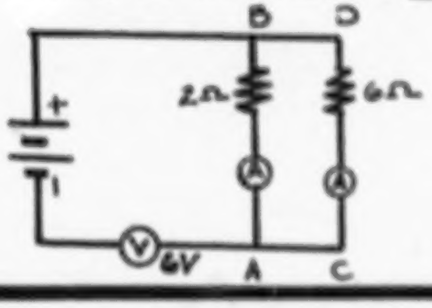
A-749

A potential divider is used to obtain a smaller [ ] than that being supplied by the battery. If a voltmeter were applied to point A and C, it would read [¢] volts. If it were applied to points A and B, it would read about [¢] volts.



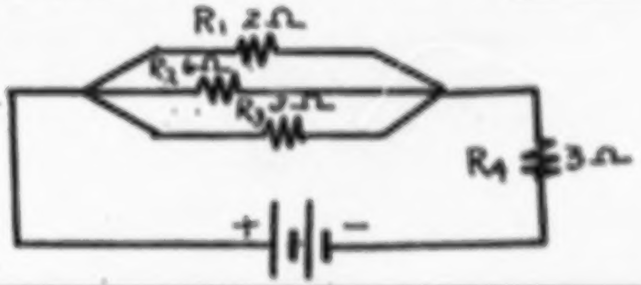
A-775

Applying the formula I = [$] in this circuit, for branch AB, I = [*] and for branch CD, I = [*].



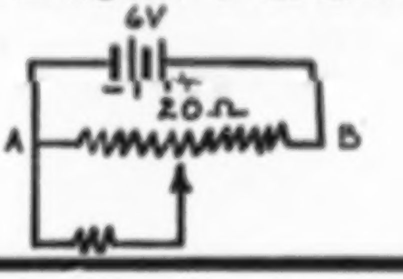
A-801

The difference of potential across the parallel portion of the circuit is [¢] volts. The current through R_1 (2 ohms) is [*], through R_2 (6 ohms) is [*], and through R_3 (3 ohms) is [*]. The current through R_4 (3 ohms) is [*].



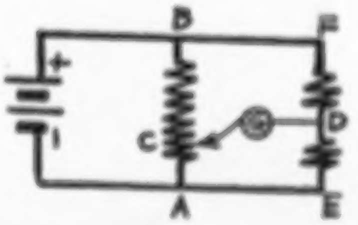
A-827

Since resistor AB is all made of the same material, the amount of resistance for any portion of it will be proportional to the [ ] of the segment. If the whole resistor produced 20 ohms, half of it would produce [¢] ohms.



A-853

It is easy to remember the formula for the Wheatstone Bridge circuit if you remember it as two proportions. The top to bottom of one side equals the top to bottom of the other, or $\frac{R_{CB}}{R_{AC}}$ = [$].



A·I·R ©1960

a-846

current

resistance

the current times the resistance between D and F

a-820

Wheatstone Bridge

a-794

parallel

series

a-768

branches

A-I-R ©1960

a-749

voltage
50
25

---

a-775

$I = \frac{V}{R}$
3 amps
1 amp

---

a-801

6
3 amps
1 amp
2 amps
6 amps

---

a-827

length
10

---

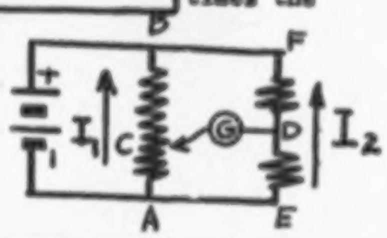
a-853

$\frac{R_{DF}}{R_{DE}}$

A·I·R ©1960

A-846

So far we have $I_1 R_{AC} = I_2 R_{ED}$ and $I_1 R_{CB} = I_2 R_{DF}$. This means that the current times the resistance between A and C is the same as the ______ times the ______ between E and F, and that the current times the resistance between C and B is the same as ** ______.

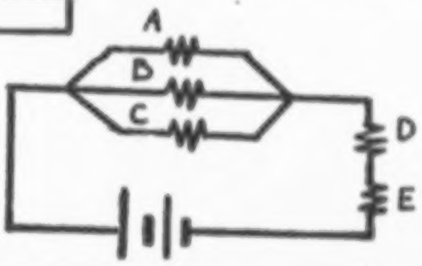


A-820

Finding the resistance of an unknown resistor can be done using a voltmeter, an ammeter, and Ohm's Law, but the results will be more accurate if we use an apparatus called a Wheatstone Bridge. In the laboratory, the special device used to measure the resistance of an unknown resistor is known as a * ______.

A-794

A circuit can consist of resistors in series and in parallel. In the circuit shown in this figure, A, B, and C are resistors in ______ and D and E are resistors in ______.



A-768

The alternate paths which the current follows in a parallel circuit are called ______.

A·I·R ©1960

A-750

Sometimes we have a 2 volt storage cell but want a source of only 1 volt difference of potential. To do this, we use a $\boxed{*\qquad\qquad\qquad}$.

A-776

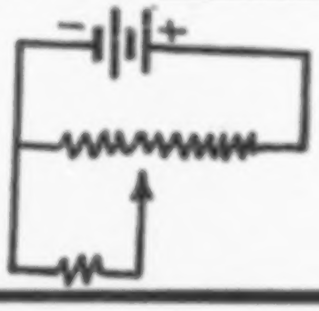
If we know the current in each branch, we can find the total current by applying Kirchhoff's Law that $I_T = \boxed{\$\qquad\qquad}$.

A-802

All the current flows through each portion of a $\boxed{\qquad\qquad}$ circuit. Only part of the current flows through each branch of a $\boxed{\qquad\qquad}$ circuit.

A-828

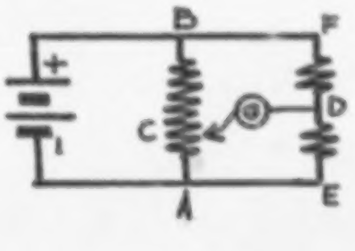
Current, as you remember, flows through a circuit from the $\boxed{\qquad\qquad}$ terminal to the $\boxed{\qquad\qquad}$ terminal. Since the long thin line indicates the positive terminal and the short thick line the negative terminal, draw arrows to indicate the direction in which current flows.

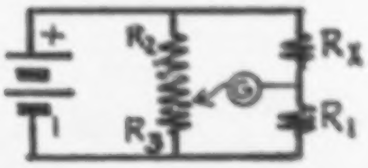


A-854

We can substitute R_X for R_{ED}, R_1 for R_{DF}, R_2 for R_{AC}, and R_3 for R_{CB}. Instead of the formula $\frac{R_{CB}}{R_{AC}} = \frac{R_{DF}}{R_{DE}}$, we can write $\frac{R_2}{R_3} = \frac{R_X}{R_1}$, or

$R_X = R_1 \boxed{\$\qquad}$.





A·I·R ©1960

a-845

$(I_1 R_{CB} =) I_2 R_{DF}$

---

a-819

resistance

3

---

a-793

Ohm's

R_E

equivalent resistance

---

a-767

3

3

A·I·R ©1960

a-750

potential divider

a-776

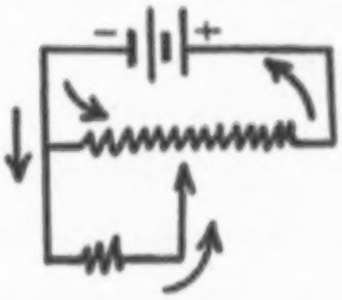
$(I_T =)\ I_1 + I_2 + I_3$

a-802

series
parallel

a-828

negative
positive



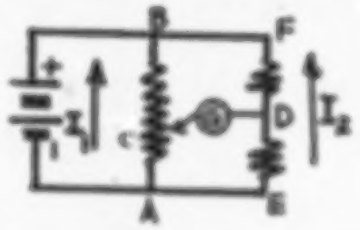
a-854

$(R_X = R_1)\ \frac{R_2}{R_3}$

A·I·R ©1960

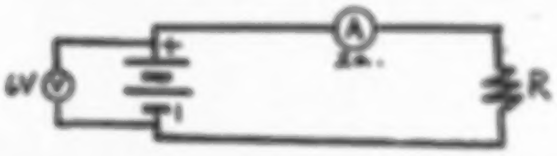
A-845

The current in branch AB is I_1. The current in EF is I_2. We can therefore simplify $I_{AC} R_{AC} = I_{DE} R_{DE}$ to read $I_1 R_{AC} = I_2 R_{ED}$.
In the same way, $I_1 R_{CB} =$ ϕ ________.



A-819

Suppose we have a material of unknown ρ or constant of ________. We can find how much resistance it will have in a circuit in two ways. First, we can use an ammeter and voltmeter. In this circuit, for instance,
R = ϕ ________ ohms.

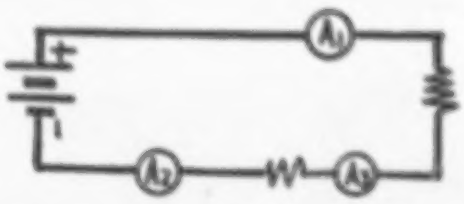


A-793

R_E, the equivalent resistance for a parallel set of resistors can be found two ways. One uses the formula $R_E = \frac{V_T}{I_T}$ which is ________ Law. The other uses the formula $\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$, in which $\frac{1}{R_E}$ is the reciprocal of ϕ ________, the * ________.

A-767

An ammeter indicates the amount of current flowing through it. In a series circuit, the same amount of current passes through all portions of the circuit. In the figure, if A_1 reads 3 amps, A_2 will read ϕ ________ amperes and A_3 will read ϕ ________ amperes.



A·I·R ©1960

A-751

In Fig. 1, the resistance of the resistor is 10 ohms, the voltmeter reads [#] volts. The voltmeter in Fig. 2 connected at the half-way point reads [#] volts or [ ] the amount in Fig. 1.

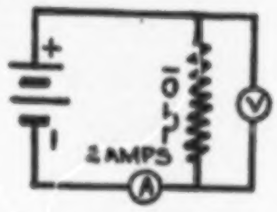


FIG. 1

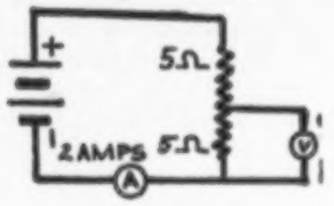
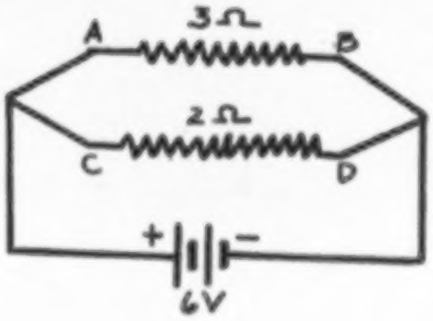


FIG. 2

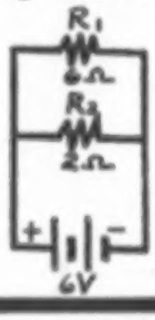
A-777

The current in branch AB is [*] and in branch CD is [*]. The total current in the circuit is therefore [*].



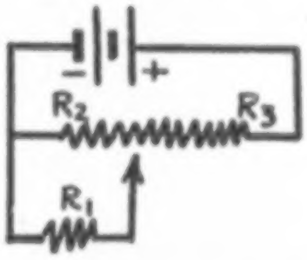
A-803

In this circuit, the current flowing through R_1 is [#] amps and the current flowing through R_2 is [#] amps. In a parallel circuit, the greatest amount of current will flow through the branch with the [ ] amount of resistance.



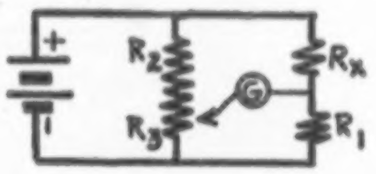
A-829

Another resistor can be added to the circuit, as shown in the figure. The new resistor, labeled R_1, forms a [ ] circuit with resistor R_2 since only part of the [ ] flows through each resistor.



A-855

Calling the resistors R_x, R_1, R_2, and R_3, as they are in the figure, write the formula for finding R_x = [$].



A·I·R ©1960

a-844

I_{DE} R_{DE}
I_{DF} R_{DF}

a-818

rho (or, ρ)

a-792

($\frac{1}{R_E}$ =) $\frac{17}{10}$
(R_E =) 1.7 ohms

a-766

11 (amps)

A·I·R ©1960

a-751

20

10

half

a-777

2 amps

3 amps

5 amps

a-803

1

3

least

a-829

parallel

current

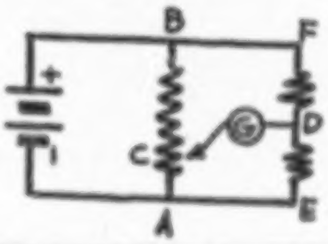
a-855

$(R_X =)\ R_1 \frac{R_2}{R_3}$

A·I·R ©1960

A-844

Since $V = IR$, we can say $V_{AC} = I_{AC} R_{AC}$ and $V_{DE} = I_{DE} R_{DE}$. Knowing that $V_{AC} = V_{DE}$ when the galvanometer reads zero, we could also say $I_{AC} R_{AC} = \boxed{\$\qquad}$. In the same way, we can say $I_{CB} R_{CB} = \boxed{\$\qquad}$.

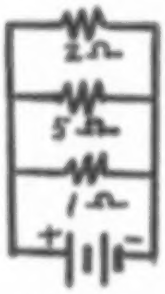


A-818

The constant of resistance of a given material is called $\boxed{\qquad}$.

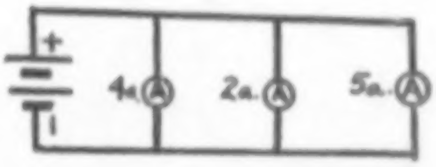
A-792

In this circuit, $\frac{1}{R_E} = \boxed{\#\quad}$ and $R_E = \boxed{*\qquad}$.



A-766

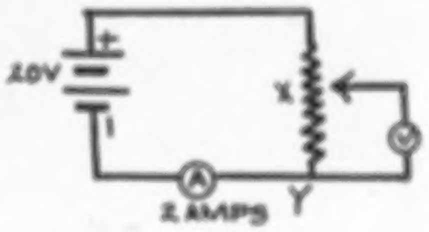
Kirchhoff discovered that the total current supplied by the battery in a parallel circuit is equal to the sum of the current in each branch, or $I_T = I_1 + I_2 + I_3$. The total current in this circuit is $\boxed{\#\quad}$ amps.



A·I·R ©1960

A-752

This circuit contains a • ________ which is 10 inches long and provides a maximum resistance of 10 ohms. To obtain half the voltage provided by the source, we would slide the contact to the ϕ ____ inch point. The difference between X and Y would then be ϕ ____ volts.



A-778

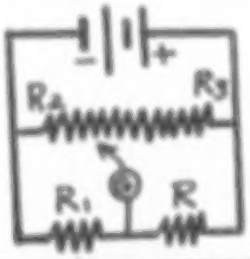
Kirchhoff's First Law is that I_T = ϕ ________. This applies only to ________ circuits. ________ Second Law is that applied voltage, or V_T = ϕ ________. This law applies only to ________ circuits.

A-804

The resistance of wires is proportional to the length and inversely proportional to the thickness of the wire. The longer the wire, the greater the ________. The thicker wire offers less ________ than a thinner wire.

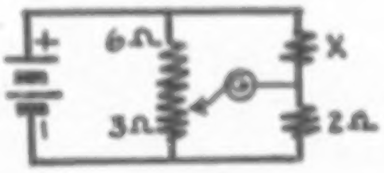
A-830

Now let us add a fourth resistor to finish the ________ Bridge circuit. In practice, this would be the resistor whose resistance we want to measure. It is called R. In this figure, we have also added a galvanometer, indicated by the symbol ϕ ____.



A-856

The value of R_X in this circuit is ϕ ________ ohms. Use the formula $\frac{R_2}{R_3} = \frac{R_X}{R_1}$, or $R_X = R_1 \frac{R_2}{R_3}$.



A·I·R ©1960

END OF UNIT

---

a-843

current

---

a-817

resistance

---

a-791

1 (ohm)

---

a-765

2
3 branches
4 branches

A·I·R ©1960

a-752

potential divider
5
10

---

a-778

$(I_T =)\ I_1 + I_2 + I_3$
parallel
Kirchhoff's
$(V_T =)\ V_1 + V_2 + V_3$
series

---

a-804

resistance
resistance

---

a-830

Wheatstone
Ⓖ

---

a-856

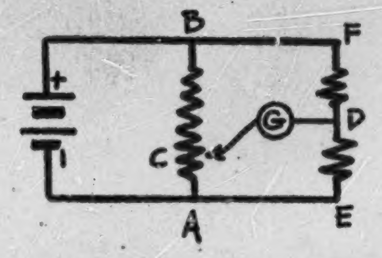
4 (ohms)

A·I·R ©1960

END OF UNIT

A-843

We know that there is no difference of potential between C and D because no ☐ is flowing when the galvanometer reads zero. We also know that A and E are at the same potential and we can therefore say that $V_{AC} = V_{DE}$.

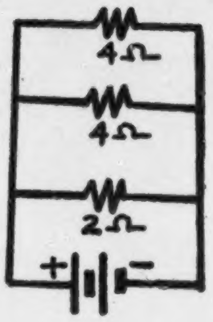


A-817

Every material has a constant of resistance called "rho" (ρ). Rho (ρ) indicates the relative ☐ produced by a given material.

A-791

In this circuit, R_E = # ohms.



A-765

Each alternate path in a parallel circuit is called a branch. The circuit in Fig. 1 has # branches. The circuit in Fig. 2 has * . The circuit in Fig. 3 has * .

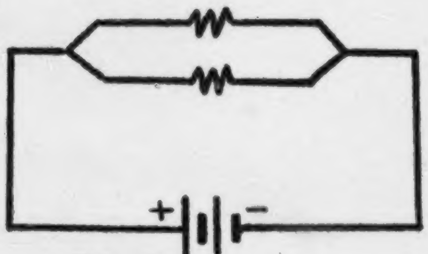


FIG. 1

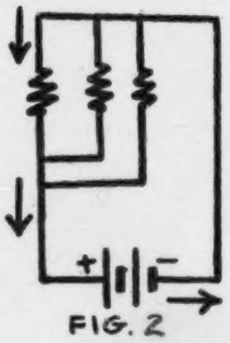


FIG. 2

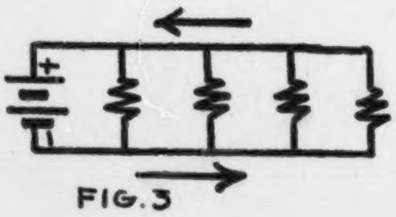
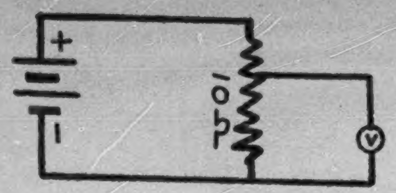


FIG. 3

A·I·R ©1960

A-753

In the circuit below, there is a 10-inch potential divider with a 10 ohm resistance. To obtain half the resistance we divide it into two 5-inch sections. Each section would then produce a resistance of # ohms.



A-779

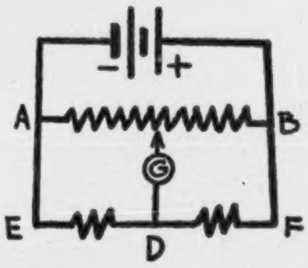
The formula V = IR is one form of * ____. The formula $I_T = I_1 + I_2 + I_3$ is known as ____ First Law. The formula $V_T = V_1 + V_2 + V_3$ is known as * ____.

A-805

Every material has its own "constant of resistance." This constant is called "rho" (say row), which is a Greek letter written ρ. The constant is the resistance in ohms for a piece of the material one meter long and one square meter in area. Silver has less resistance than iron so silver has a smaller $ ____ than iron.

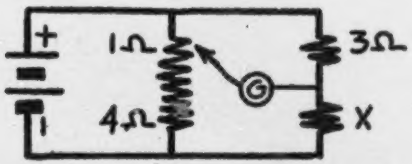
A-831

For current to flow, there must be a difference of ____. Current will flow from A to B and from E to F. Current will only flow from C to D, however if there is a * ____ between C and D. For the next several questions, it is important to watch the figures closely to be sure to see which part of the circuit you are to look at.



A-857

For this circuit, R_X is in a different place. You will get the correct answer if you remember the proportion top to bottom equals the proportion top to bottom. The value of R_X in this circuit is # ohms.



A·I·R ©1960

a-868

Wheatstone Bridge

$(R_X =)\ R_1 \frac{R_2}{R_3}$ (or, $\frac{R_X}{R_1} = \frac{R_2}{R_3}$)

---

a-842

galvanometer

difference of potential

---

a-816

sum of the voltages for each portion (or, for each bulb)

11

---

a-790

$\frac{6}{6}$ (or, $\frac{1}{1}$)

1 (ohm)

---

a-764

parallel

A·I·R ©1960

a-753

5

---

a-779

Ohm's Law

Kirchhoff's

Kirchhoff's Second Law

---

a-805

ρ (or, rho)

---

a-831

potential

difference of potential (or, potential difference)

---

a-857

12 (ohms)

A·I·R ©1960

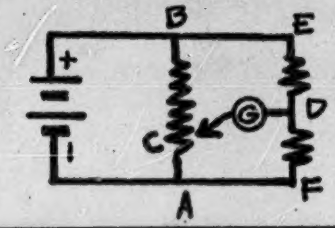
A-868

In order to determine the value of an unknown resistor, we use a circuit or apparatus called a * . The formula for finding the value of R_X is R_X =

$.

A-842

In using the Wheatstone Bridge, we adjust the potential divider until the indicates that no current is flowing between C and D. Current only flows when there is a * .



A-816

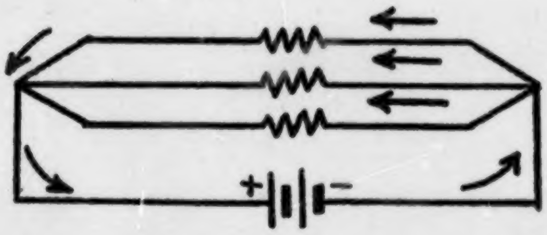
When bulbs are in series, the total applied voltage equals the ** . If there are 10 bulbs in the circuit and we use a source of 110 v, each bulb must account for an IR drop of one tenth of the total applied voltage, or # volts.

A-790

Three resistors are connected in parallel. If R_1 is 6 ohms, R_2 is 3 ohms, and R_3 is 2 ohms, $\frac{1}{R_E}$ = # and R_E = # ohm.

A-764

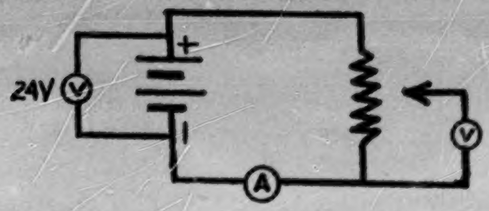
In a series circuit, the current has only one path to follow. In a parallel circuit, the current is divided. The current follows several paths in a circuit.



A·I·R ©1960

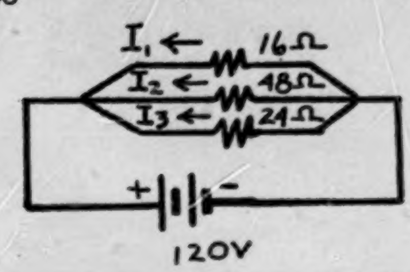
A-754

In the figure, we have a 24 volt source of power. If we want only 12 volts we could obtain this by dividing the resistance of the potential divider in half. In other words, by using only half the resistance, we obtain half the ________.
If we use one-third of the resistance, we would have ** ________.



A-780

Using ________ Law, $I_1 = \frac{120\ v}{16} = 7.5$ amps, $I_2 = \frac{120\ v}{48} = 2.5$ amps and $I_3 = \frac{120\ v}{24} =$ * ________. Using ________ First Law,
7.5 amps + 2.5 amps + * ________ = * ________.



A-806

Copper, a good conductor, has a smaller $ ________ than paper, an insulator. A resistor is made of material which has a higher $ ________ than the wire usually used in circuits.

A-832

In Figure 1, point D is at lower potential (more negative) than point C. Current will flow from D to C since there is a * ________ ________. In Figure 2, point D is at higher potential (less negative) than point C. Current (will/will not) ________ flow from point C to D.

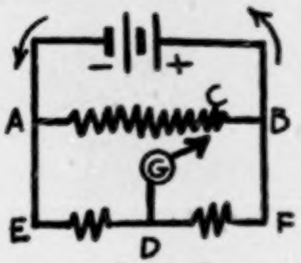


FIG. 1

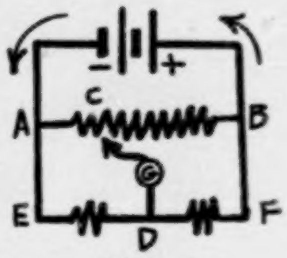
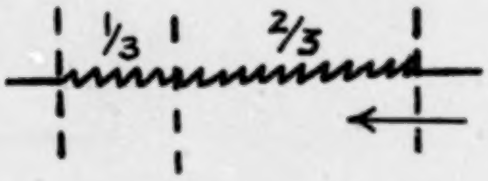


FIG. 2

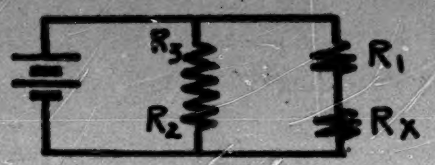
A-858

For a resistor made of a uniform material, we know that resistance is proportional to the ________ of the segment. In the figure, if the whole resistor is 12 ohms, one-third would be # ________ ohms and the remaining two-thirds would represent # ________ ohms.



A·I·R ©1960

a-867



(the place you put R_x, R_1, R_2 and R_3 does not make any difference so long as you remember that $\frac{R}{R} = \frac{R}{R}$ when the galvanometer reads zero)

a-841

Ohm's Law
I_{BC} R_{BC}
I_{ED} R_{ED}
I_{DF} R_{DF}

a-815

110 volts
55 (ohms)
2 (amps)

a-789

$(\frac{1}{R_E} =) \frac{1}{R_1} + \frac{1}{R_2}$
$(\frac{1}{R_E} =) \frac{2}{4}$ (or, $\frac{1}{2}$)
$(R_E =)$ 2 (ohms)

a-763

parallel

A·I·R © 1960

377

a-754

voltage (or, difference of potential)
one-third of the voltage

a-780

Ohm's
5.0 amps
Kirchhoff's
5.0 amps
15 amps

a-806

ρ (or, rho)
ρ (or, rho)

a-832

difference of potential
will

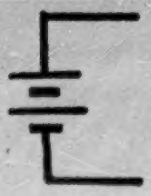
a-858

length
4
8

A·I·R ©1960

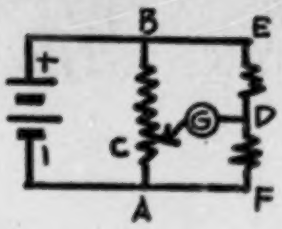
A-867

Draw a Wheatstone Bridge circuit, labeling each of the four resistors R_X, R_1, R_2, R_3.



A-841

[*] says V = IR. Therefore, the voltage across AC equals current across AC times the resistance across AC, or in symbols, $V_{AC} = I_{AC} R_{AC}$. In the same way, V_{BC} = [$], V_{ED} = [$] and V_{DF} = [$].



A-815

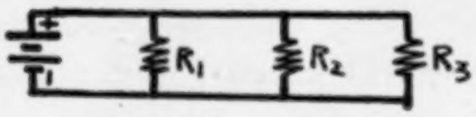
The electric company supplies houses with a voltage of 110 v. If we plug a Christmas tree light set which is wired in series into house current, we know the voltage across the entire circuit must be [*]. If each of the 10 bulbs has a resistance of 5.5 ohms, R_T is [#] ohms, so [#] amps of current flow through the circuit.

A-789

In another circuit, there are two parallel resistances. If R_1 is 4 ohms and R_2 is 4 ohms, to find R_E, we use the formula $\frac{1}{R_E}$ = [$]. In this circuit, then, $\frac{1}{R_E}$ = [#] and R_E = [#] ohms.

A-763

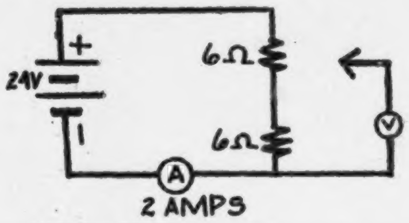
Resistors can be connected in parallel. In the figure, only part of the current passes through each resistor. This is therefore a [ ] circuit.



A·I·R ©1960

A-755

In the figure, there are two resistors with a resistance of # ohms each. To obtain half of the voltage provided by the battery, the contact is connected between the resistors. The voltmeter will then read # volts.



A-781

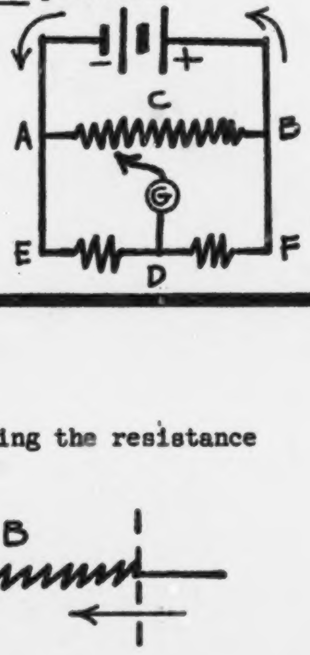
So far you have learned that, in a parallel circuit, the voltage across the entire circuit is equal to the voltage across any ________, and the current in the circuit is equal to the sum of the current in each of the ________.

A-807

Rho (ρ) indicates the relative ________ produced by a given material. Good conductors have low ________.

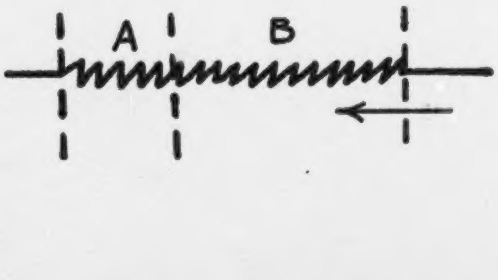
A-833

At some point along the variable resistor, point C will have the same potential as point D. Then current will not flow from C to D or from D to C. The ________ will indicate zero ________ is flowing.



A-859

For a resistor made of a given material, a proportion made by dividing the resistance of one portion by the resistance of the remainder will be the same as a ________ made by dividing the length of the first portion by the ________ of the remainder: $\frac{R_A}{R_B} = \frac{\text{length A}}{\text{length B}}$.



A·I·R ©1960

a-866

galvanometer
flowing

a-840

I_{ED} (=) I_{DF}

a-814

each portion of the circuit (or, each bulb)
opened

a-788

$\frac{1}{3} + \frac{1}{2}$ (= $\frac{1}{R_E}$)

($\frac{1}{R_E}$ =) $\frac{5}{6}$

(R_E =) $\frac{6}{5}$

(R_E =) 1.2

a-762

CD

A·I·R ©1960

a-755

6
12

a-781

branch (resistor)
branches (resistors)

a-807

resistance
rho's (or, ρ's)

a-833

galvanometer
current

a-859

proportion
length

A·I·R ©1960

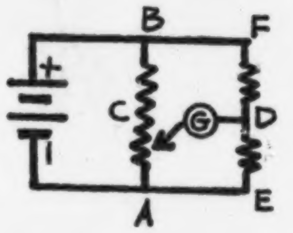
A-866

To use a Wheatstone Bridge to determine the value of a resistor, we insert R_X into the circuit and then adjust the slide on the variable resistor until the $\boxed{}$ indicates that no current is $\boxed{}$.

A-840

The current flowing through AB is called I_1. The current flowing through EF is I_2. We know then, that $I_1 = I_{AC} = I_{CB}$ and $I_2 =$

$\boxed{\$} = \boxed{\$}$.



A-814

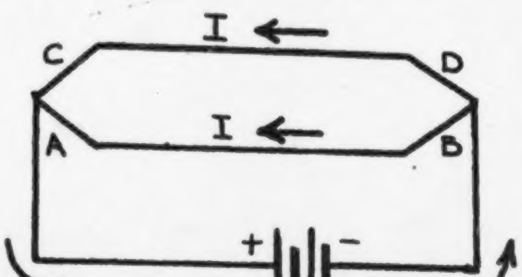
Some Christmas tree lights are wired in series. This means all the current has to flow through $\boxed{**}$. If one bulb burns out, the circuit will be $\boxed{}$ and current will no longer flow. All the bulbs will then go out.

A-788

If $R_1 = 3$ ohms and $R_2 = 2$ ohms, find R_E using the formula $\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_E}$. $\frac{1}{\boxed{\#}} + \frac{1}{\boxed{\#}} = \frac{1}{R_E}$. The lowest common denominator is 6, so $\frac{1}{R_E} = \frac{\boxed{\#}}{\boxed{\#}}$. Next invert the numbers, $R_E = \frac{\boxed{\#}}{\boxed{\#}}$, and divide $R_E = \boxed{\#}$.

A-762

A parallel circuit is one in which only part of the current passes through each portion of the circuit. As can be seen in the figure, part of the current passes through the wire AB and part passes through wire $\boxed{\$}$.



A·I·R ©1960

A-756

In Figure 1 the 5-inch resistor has a resistance of 10 ohms. The total voltage of the circuit is # volts. In Figure 2, the voltmeter is connected at the 3-inch point. The voltage across that part of the circuit is # volts. In Figure 3, the voltmeter is connected at the 2-inch point. The voltage across that part of the circuit is # volts.

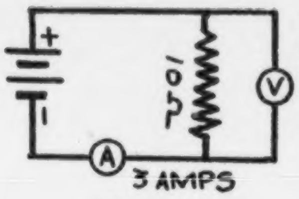


FIG. 1

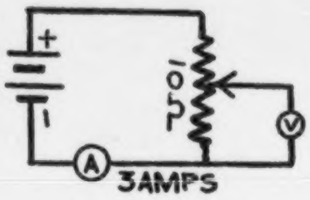


FIG. 2

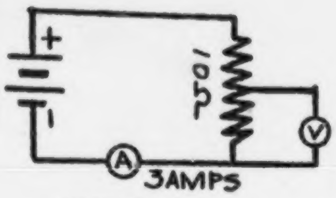


FIG. 3

A-782

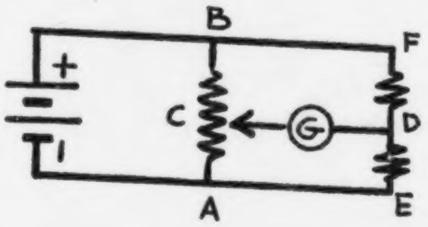
In a series circuit, the total resistance of a circuit is equal to the sum of the resistors in the circuit. In a parallel circuit, however, we use an equivalent resistance. The ☐ resistance of a parallel circuit is not equal to the sum of the resistances.

A-808

Our houses are wired in parallel, and the electric company supplies us with a constant potential difference of about 110 v. When we add more lamps or more appliances to a circuit, we do not change the ☐, but by adding more resistance in parallel, we change the amount of ☐ flowing through the wires.

A-834

When the galvanometer indicates no current is flowing between C and D, we know points C and D have the same ☐. Points A and E also have the same ☐ because there is no resistance between them. (Remember, we assume wires used to make a circuit represent no ☐).



A-860

In a given material, the resistance is proportional to the ☐ of the material. Therefore, we do not have to have the resistance value of R_2 and R_3 as long as we know their ☐.

A·I·R ©1960

a-865

$(R_X =)\ R_1 \dfrac{R_2}{R_3}$ (or, $\dfrac{R_X}{R_1} = \dfrac{R_2}{R_3}$)

6

---

a-839

the same as

B

---

a-813

equivalent

220 ohms

.5

---

a-787

$R_E = \frac{8}{2}$ or 4

---

a-761

parallel

A·I·R ©1960

385

a-756

30

18

12

a-782

equivalent

a-808

voltage

current

a-834

potential

potential

resistance

a-860

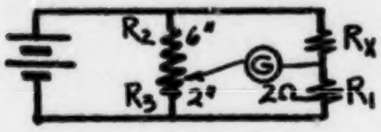
length

lengths

A·I·R ©196C

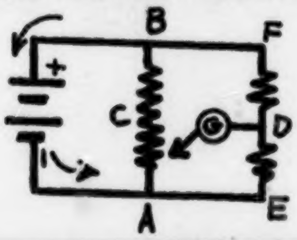
A-865

In the figure, the value of R_1 is 2 ohms, R_2 is 6 inches, and R_3 is 2 inches. Using the formula $R_X = \boxed{\$\qquad\qquad}$, the value of R_X in ohms for this circuit is $\boxed{\#\qquad}$ ohms.



A-839

In a series circuit, the current flowing through one section is (the same as/different than) $\boxed{}$ the current in any other section. The current flowing from A to C must be the same as that flowing from C to $\boxed{\$\quad}$.



A-813

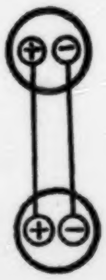
If 10 Christmas tree lights are in parallel and each bulb has a resistance of 2200 oh ,
the R_E, or $\boxed{}$ resistance, will be $\boxed{*\qquad\qquad}$. If the house voltage is 110 v.
the total current flowing through the circuit will be $\boxed{\#\qquad}$ amps.

A-787

When we have found $\frac{1}{R_E}$, which is the reciprocal of R_E, we can find R_E by inverting the numerator and denominator and then dividing. For instance, if $\frac{1}{R_E} = \frac{2}{4}$, then $R_E = \frac{4}{2}$ or 2. If $\frac{1}{R_E} = \frac{3}{6}$, $R_E = \frac{6}{3}$ or 2. If $\frac{1}{R_E} = \frac{2}{8}$, $R_E = \dfrac{\boxed{\#\quad}}{\boxed{\#\quad}}$ or $\boxed{\#\quad}$.

A-761

Cells can also be connected in parallel. Cells in parallel have the positive terminal of one cell connected to the positive terminal of the other. The negative terminals are also connected to each other. The electromotive force of a battery will not be raised when cells are connected in $\boxed{}$.



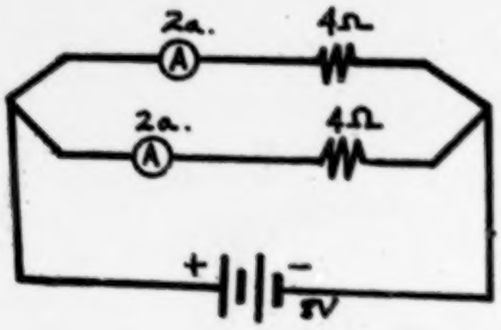
A·I·R ©1960

A-757

To obtain a smaller amount of voltage in a circuit, a device called a [*] is used. By making contact with its resistor at varying points, the resistance obtained is decreased proportionally to the length and the [ ] obtained is therefore decreased proportionally.

A-783

To compute the equivalent resistance for this circuit, we can use the formula $R_E = \frac{V}{I_T}$. Then, $R_E = \frac{8}{2+2}$, or $R_E =$ [#] ohms. From this example, you can see that the equivalent resistance (is/is not) [ ] equal to the sum of the resistances.

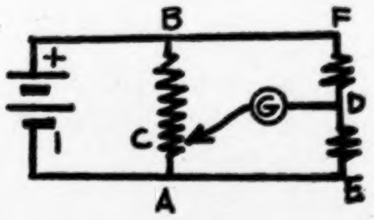


A-809

A light bulb is like a resistor. When the bulb "burns out," the conductor inside the bulb has broken and current will no longer flow. When the light is burning, the circuit is (open/closed) [ ] and when the bulb is burned out, the circuit is [ ].

A-835

When the galvanometer reads zero, we know C has the same potential as [$].
We also know A has the same potential as [$],
and also that B has the same potential as [$].
As you read each question, point to the part of the figure mentioned. This will help you understand.



A-861

We do not have to know the actual resistance value of resistors R_2 and R_3 to determine the value of R_X using a Wheatstone Bridge. We only need to know [ ] of R_2 and R_3 since they are made of the same [ ].

A·I·R ©1960

a-864

3

---

a-838

difference of potential
difference of potential

---

a-812

$\frac{1}{2}$ (or, .5)

---

a-786

3
3
$(\frac{I}{R_E} =)\ \frac{2}{3}$

---

a-760

negative
sum

A·I·R ©1960

a-757

potential divider
voltage

---

a-783

2
is not

---

a-809

closed
open

---

a-835

D
E
F

---

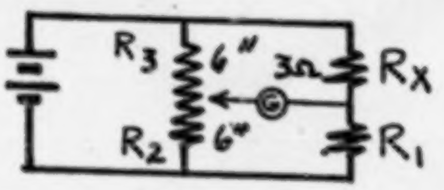
a-861

length
material

A·I·R ©1960

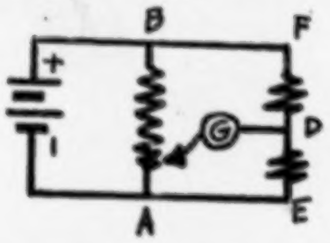
A-864

Using the formula $R_X = R_1 \frac{R_2}{R_3}$, the value of R_X in ohms will be $\boxed{\#}$. If R_1 is 3 ohms, R_2 is 6 inches long, and R_3 is 6 inches long.



A-838

$V_{CB} = V_{DF}$ means that the $\boxed{*}$ between CB is the same as the $\boxed{*}$ between D and F.



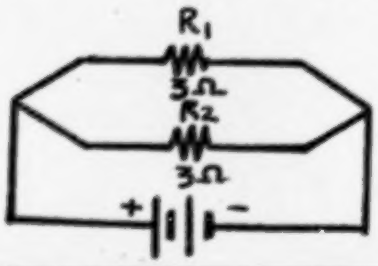
A-812

If 6 Christmas tree lights are in parallel and each bulb has a resistance of 3 ohms, the total equivalent resistance will be $\boxed{\#}$ ohms.

A-786

To find the equivalent resistance in this circuit we can use the formula $\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_E}$.

Since $\frac{1}{R_1} = \frac{1}{\boxed{\#}}$, and $\frac{1}{R_2} = \frac{1}{\boxed{\#}}$, there is already a common denominator. Thus, we can add and we get $\frac{1}{R_E} = \frac{\boxed{\#}}{\boxed{\#}}$.



A-760

When two cells are connected in series, the positive terminal of one is connected to the $\boxed{\quad}$ terminal of the other. The voltage of the cells in series is the $\boxed{\quad}$ of the individual cell voltages.

A·I·R ©1960

A-758

The resistance produced by a portion of a resistor is proportional to the length of the portion used. To decrease the supplied voltage with a [*], we decrease the [ ] of the portion used.

A-784

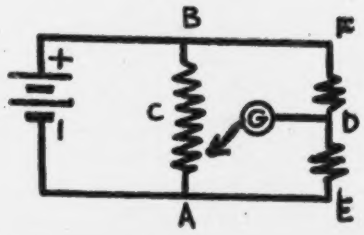
The equivalent resistance of several resistors in parallel can be found using the formula $\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{R_E}$. A number written like $\frac{1}{R}$ is called the reciprocal of R. The number $\frac{1}{X}$ is the reciprocal of X. The number $\frac{1}{M}$ is the [*] and the number $\frac{1}{16}$ is the [*].

A-810

Some Christmas tree lights are wired in parallel with each bulb forming one branch. When a light burns out, that [ ] of the circuit is (opened/closed) [ ] but current continues to flow through the other branches.

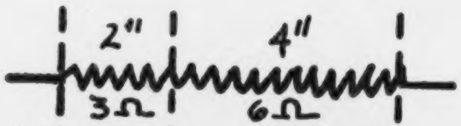
A-836

When the galvanometer reads zero, we know that the difference of potential or voltage between A and C is the same as that between E and D. We also know the voltage between C and B is the same as that between [$] and [$].



A-862

In the figure, using the values in ohms, the proportion $\frac{R_2}{R_3}$ is [#]. Using the values in lengths, the proportion $\frac{R_2}{R_3}$ is [#]. In the formula $R_X = R_1 \frac{R_2}{R_3}$ it (does/does not) [ ] make a difference whether we use lengths or ohms for R_2 and R_3.



A·I·R ©1960

a-863

lengths

2.5

---

a-837

V_{ED}

0 (zero)

---

a-811

110 (volts)

---

a-785

common denominator

---

a-759

flows through each part of the circuit in turn

A·I·R ©1960

393

a-758

potential divider
length

a-784

reciprocal of M
reciprocal of 16

a-810

branch
opened

a-836

D (and) F

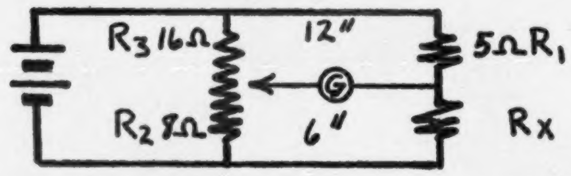
a-862

2
2
does not

A·I·R ©1960

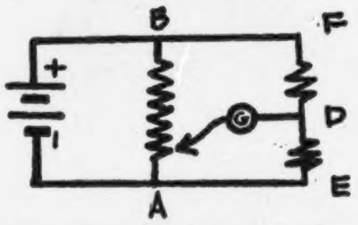
A-863

In this circuit, with information given, the value of R_X can be computed two ways, by using the resistance of R_2 and R_3 or the [ ] of R_2 and R_3. The value of R_X is [#] ohms.



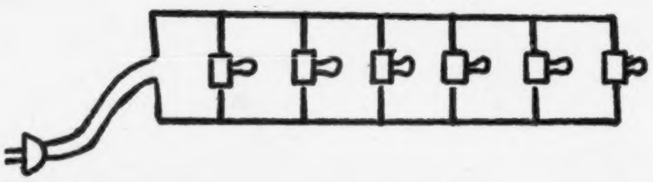
A-837

The difference of potential between A and C can be written in symbols as V_{AC}. The difference of potential between E and D can be written as [$]. We can therefore say, in symbols, $V_{AC} = V_{ED}$ when the galvanometer reads [#]



A-811

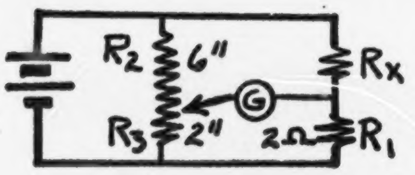
For use on 110 v house current, each Christmas tree bulb, if it is wired in parallel, should be rated at [#] volts.



A-785

To find the equivalent resistance in this circuit we can use the formula $\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_E}$.

To compute the result, we first substitute, $\frac{1}{3} + \frac{1}{6} = \frac{1}{R_E}$. To add $\frac{1}{3} + \frac{1}{6}$, we have to find a common denominator. In this case, 6 is the [*] of $\frac{1}{3}$ and $\frac{1}{6}$.



A-759

We have already talked about a series circuit. A series circuit is one in which the current [**].

A·I·R ©1960

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

PRECEDING PAGE BLANK- NOT FILMED

UNIT EIGHT

ELECTRIC FIELD AND CAPACITANCE

Steps A-869 through A-985

BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

UNIT ENDS HERE

A-869

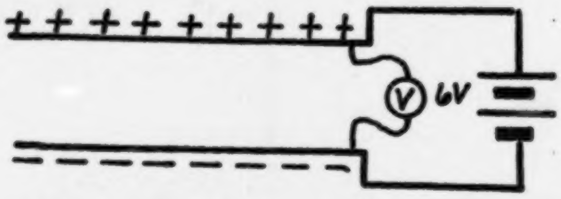
One way of describing the force of attraction or repulsion of one charge upon another is by the term electric field. Around every charged object there is an [ ] field.

A-893

In symbols, Coulomb's Law is written as F = [$]. This means that as the size of the charges on either of the objects increases, the force (increases/decreases) [ ], and that as the distance between them increases, the force (increases/decreases) [ ].

A-917

The formula usually used to calculate electric field intensity is the one using volts and meters. Two plates, 1 meter apart, with 6 volts potential between them form an electric field with an intensity of [#] volts per meter or newtons per coulomb.



A-941

The substance separating the two plates of a capacitor is called the dielectric. The dielectric may be air, glass, paper, or rubber. From this list we can see that an insulator or insulating material is used as the [ ] in a capacitor.

A-965

When a capacitor is charged, the dielectric material becomes polarized which means the [ ] in all the atoms are [**].

A·I·R ©1960

a-964

electrons
side

a-940

increases the capacitance

a-916

electric field intensity

(E =) $\frac{F}{Q'}$

(E =) $\frac{V}{d}$

a-892

force
constant
charges
distance

A·I·R ©1960

401

a-869

electric

a-893

$F = k \frac{QQ'}{d^2}$

increases

decreases

a-917

6

a-941

dielectric

a-965

electrons

drawn or pulled to one side (of their atoms)

A·I·R ©1960

A-964

As you remember from your study of static electricity, conductors differ from insulators in that insulators have no free ______. Insulators can be polarized, however, which means that the electrons in the atoms are all drawn toward the same ______ of their atoms.

A-940

Increasing the area of overlap of the plates in a capacitor ** ______.

A-916

There are two formulas for calculating E, the * ______, between charged parallel plates. One uses force and charge, or E = $ ______. The other uses volts and distance, or E = $ ______.

A-892

Coulomb's Law is written as $F = k \frac{QQ'}{d^2}$. The formula means that F, the amount of ______ of attraction or repulsion is equal to k, a ______, times QQ', the product of the size of the two ______, divided by d^2, or the ______ between them squared.

A·I·R ©1960

A-870

Electric field means the space around a charged object in which another charge will be attracted or repelled. A test charge will be ______ or ______ by a charged object if it is placed in the charged object's electric field.

A-894

Coulomb's Law also gives the intensity of the electric field at any point around a charged object. The closer a + test charge is to the object, or the greater the amount of charge on the object, the greater will be the ______ of the electric field at that point.

A-918

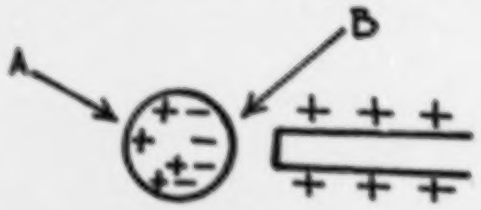
Two plates, .5 meters apart, with 12.5 volts difference of potential will have an electric field intensity of ______ volts per meter or newtons per ______.

A-942

In a capacitor, the substance between the two plates is called the ______. Insulators are always used as the ______.

A-966

If we take a + charged rod and touch an insulator such as a pith ball, many atoms in the pith ball will become polarized. While the ball will remain electrically neutral, side B of the ball will become ______ charged.



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a-963

distilled water

a-939

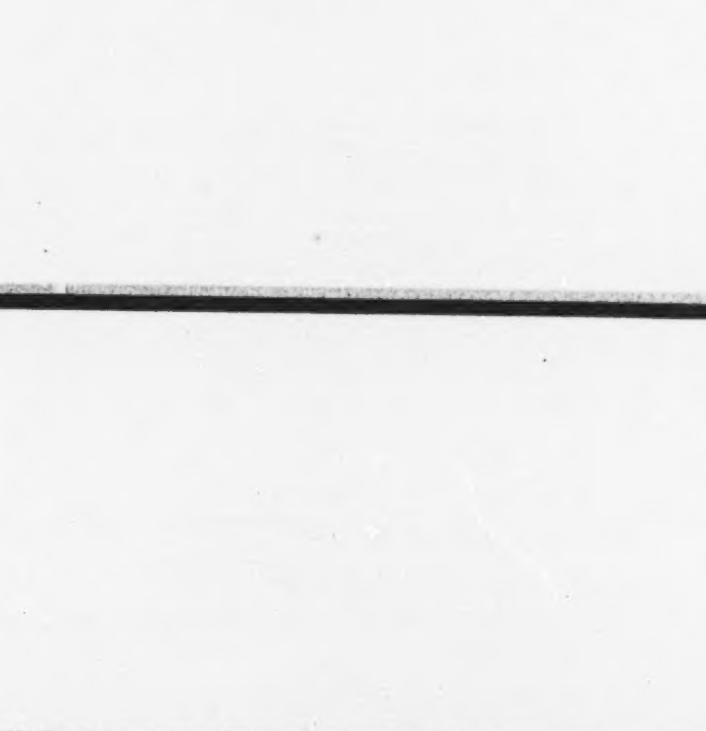
increases the capacitance

a-915

potential
volts

a-891

positive (+) test charge
electric field



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a-870

attracted (repelled)
repelled (attracted)

a-894

intensity

a-918

25
coulomb

a-942

dielectric
dielectric

a-966

negatively

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A-963

The higher the dielectric constant, the higher the capacitance obtainable. The k for air is 1, for paper or wax it is about 2, for glass it is about 8, and for distilled water (water with no impurities) it is about 81. Of these five materials, we could get the greatest capacitance by separating the plates with $\boxed{*\qquad\qquad\qquad}$.

A-939

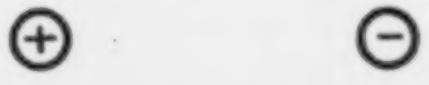
Decreasing the distance between the plates of a capacitor $\boxed{**\qquad\qquad\qquad\qquad}$ $\boxed{\qquad\qquad\qquad}$.

A-915

To measure the electric field intensity between the plates, we can divide the difference of $\boxed{\qquad\qquad}$, in volts, by the distance between the plates in meters. Thus, $E = \frac{V}{d}$ or, intensity = $\frac{\boxed{\qquad\qquad}}{\text{meters}}$.

A-891

Draw lines of force for these charged objects. The lines of force indicate the direction in which a $\boxed{*\qquad\qquad\qquad\qquad}$ will move if it is placed at any point in either objects' $\boxed{*\qquad\qquad}$.



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A-871

Earlier, when you studied Coulomb's Law, you learned that the force of ________ or ________ was greater the (closer to/farther away) ________ a + test charge was to a charged object.

A-895

The intensity of an electric field at any point is symbolized by the letter "E". E, the ________ of an electric field, is equal to F, or the ________ on the test charge (computed by Coulomb's Law), divided by Q', the size of the test charge. In symbols, $E = \frac{F}{Q'}$.

A-919

Capacitance is the ability or "capacity" of a device to store electric charge. Two charged parallel metal plates, such as those we used to obtain a uniform electric field have the ability to store electric charge; they have a ________.

A-943

The capacitance depends on the ________ between the two plates and the area of overlap of the ________. It also depends on the material separating the plates known as the ________.

A-967

In a capacitor, the dielectric material becomes polarized when the plates are charged. If the dielectric is removed from the capacitor, it will still be ________, providing it is not put in another ________ field.

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END OF UNIT

---

a-962

capacitance
dielectric

---

a-938

capacitance

---

a-914

battery
positively (negatively)
negatively (positively)
potential

---

a-890

lines of force
move
electric field
direction

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a-871

attraction (repulsion)
repulsion (attraction)
closer to

a-895

intensity
force

a-919

capacitance

a-943

distance
plates
dielectric

a-967

polarized
electric

A·I·R ©1960

END OF UNIT

A-962

A device for collecting or storing charge is called a capacitor. For plates of a constant area and a constant distance apart, the ______ will depend on the insulating material or ______ between them.

A-938

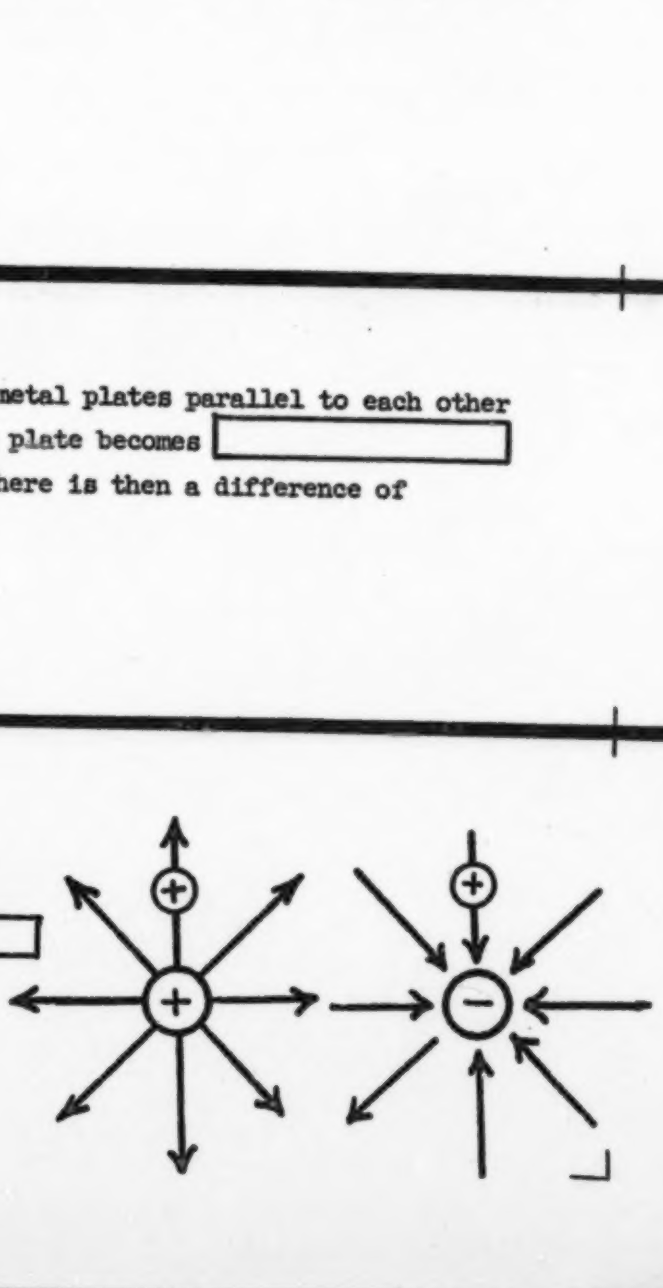
Decreasing the distance between the plates of a capacitor increases the ______.

A-914

To produce a uniform electric field, we place two metal plates parallel to each other and connect them to the terminals of a ______. One plate becomes ______ charged and the other becomes ______ charged. There is then a difference of ______ between the two plates.

A-890

The arrows or * ______ indicate the direction in which a positive test charge would tend to ______ in the * ______. If the test charge were negative instead of positive, the ______ of the electric field would be reversed.



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A-872

The electric ☐ describes the way a charge is acted upon by another charged object. The intensity of the field at any point, is the strength of repulsion or attraction on a + test charge placed at that point. The greater the strength of attraction or repulsion, the greater the ☐ of the electric field.

A-896

To find E, or the ☐ of an electric field around a charged object, we use the formula $E = \frac{F}{Q'}$. To compute E this way, we would first use Coulomb's Law, F = ☐ $. Then, we would divide F by Q', the size of the test charge.

A-920

Two charged parallel metal plates can store electric charge; that is, they have a ☐.

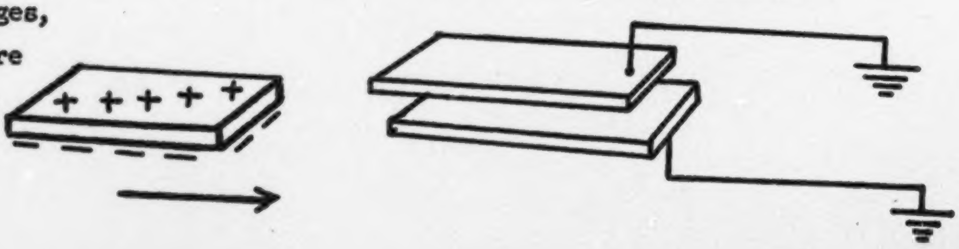
A-944

The capacitance depends upon three factors: the

1. ☐ ** .
2. ☐ ** .
3. ☐ ** .

A-968

In the figure, there is an electrically polarized sheet of dielectric material which will be inserted in an uncharged capacitor. The side of the sheet toward which the electrons were drawn will attract ☐ $ charges, and the side away from which they were drawn will attract ☐ $ charges.



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a-985

series

1 (mfd) ($\frac{1}{C_E} = \frac{1}{2} + \frac{1}{6} + \frac{1}{3} = \frac{6}{6} = 1$)

a-961

(C =) $\epsilon_0 k \frac{A}{D}$

a-937

increased

a-913

E
electric field intensity

a-889

lines of force (or, electric field)
repel
repelled

A·I·R ©1960

a-872

field
intensity

---

a-896

intensity

$F = k \frac{QQ'}{d^2}$

---

a-920

capacitance

---

a-944

distance between the plates
area of overlap of the plates
dielectric between the plates

---

a-968

+ (positive)
- (negative)

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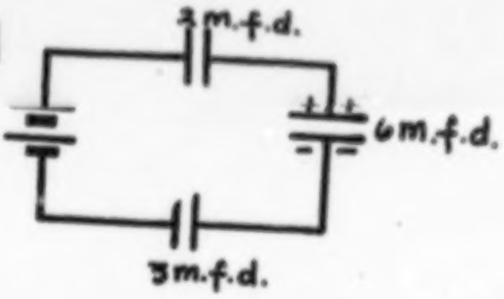
A-985

The equivalent capacitance in the ☐ circuit below is # mfd.



A-961

To find capacitance for capacitors with parallel plates, we can use the permittivity constant, the dielectric constant for the material we are using, and the plate area and distance. The formula is C = $.

A-937

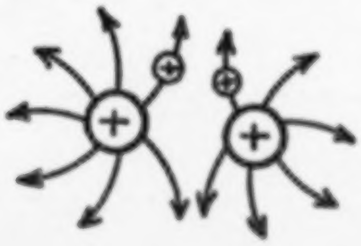
If the area over which the plates overlap is increased, there can be more charge per volt and the capacitance is (increased/decreased) ☐.

A-913

In the m.k.s. system of units, newtons per coulomb equals volts per meter. Therefore, either $\frac{V}{d}$ or $\frac{F}{Q}$, will each give us $ or the * ☐.

A-889

The figure shows the * around two positively charged objects. The pattern results from the fact that like charges ☐. No matter where a positive test charge is placed in the field, it will be ☐ by both objects.



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A-873

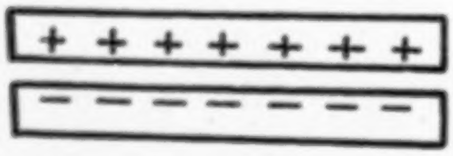
The force on a test charge of any size at some point in an [*] is given by Coulomb's law. The force of attraction or repulsion on a + test charge of one coulomb is called the intensity of the electric [ ].

A-897

Because $F = k\frac{QQ'}{d^2}$, we can also write $E = \frac{F}{Q'}$, as $E = \frac{kQQ'}{d^2Q'}$. Then, by dividing the numerator and denominator by Q', or "canceling", we get $E = k\frac{Q}{d^2}$. Since Q' stands for the size of the + test charge, Q stands for the amount of [ ] on the object creating the electric [ ].

A-921

To have a capacitance, two charged parallel metal plates must be separated by an insulator, such as air. If we connect the two plates with a conductor, they will no longer have a [ ] because electrons will flow from the [$] plate to the [$] plate.



A-945

One kind of capacitor consists of two sheets of aluminum foil with a piece of plastic between them. The piece of plastic is the [ ]. The aluminum foil sheets are the [ ].

A-969

The ability of a capacitor to store charges depends on k, the [ ] constant of the material used between the plates. The more easily the material will polarize, the greater the amount of charge the capacitor will store. Since distilled water has a high k, we know it will [ ] easily and store a (large/small) [ ] amount of charge.

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a-984

parallel
8 (mfd)

a-960

$(C = \epsilon_o k) \frac{A}{D}$
$(C =) \frac{Q}{V}$

a-936

capacitance

a-912

electric field intensity (or, intensity of the electric field)

a-888

lines (of) force
attract
electric field
attracted

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a-873

electric field
field

---

a-897

charge
field

---

a-921

capacitance
-
+

---

a-945

dielectric
plates

---

a-969

dielectric
polarize
large

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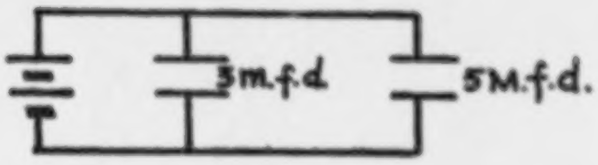
A-984

The total capacitance in the ______ circuit below is [$] mfd.



A-960

The formula for the capacitance of capacitors with parallel plates, which uses plate area and distance is $C = \epsilon_0 k$ [$]. The other formula for capacitance, using charge and voltage, is C = [$].

A-936

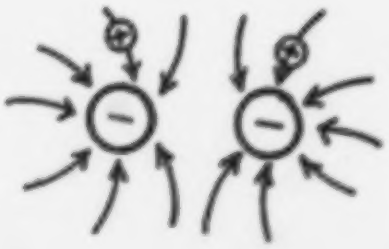
Increasing the size of the plates also increases the capacitance. The larger the plates, the more charge that can be stored per volt and therefore the ______ is increased.

A-912

In the system of units we have been using, the m.k.s. system, one newton per coulomb equals one volt per meter. Therefore, we can also measure E, the [*] ______ as volts per meter or $E = \frac{V}{d}$.

A-888

The figure shows the arrows or ______ of ______ around two negatively charged objects. The pattern results from the fact that unlike charges ______. No matter where a positive test charge is placed in the [*] it will be ______ by both objects.



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A-874

The force of attraction or repulsion between a charged object and a one coulomb + test charge is known as the ________ of the * ________.

A-898

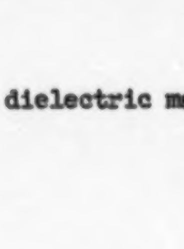
Using algebra, we could also say that E, the ________ of an electric field at any point around a small object, equals a constant times the size of the charge on the object, divided by the distance squared. The formula is $\boxed{\$\quad} = k\,\frac{Q}{d^2}$.

A-922

Capacitance is measured as the charge which is stored by parallel plates, divided by the difference of potential between the plates. Capacitance then, equals coulombs per ________, or $C = \frac{Q}{V}$.

A-946

You can make one kind of a capacitor called a Leyden Jar by covering the inside and outside of a glass jar with aluminum foil. To get a large capacitance, we would use a (large/small) ________ jar made of (thick/thin) ________ glass. The figure shows a homemade capacitor known as a * ________.



A-970

Most of the energy stored by a capacitor is actually stored in the dielectric material. This is because the atoms of the dielectric become ________.

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a-983

parallel
series

---

a-959

k

---

a-935

close together (or, as close as possible)

---

a-911

force (or) F

---

a-887

test charge
repelled
attracted

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421

a-874

intensity
electric field

a-898

intensity
E

a-922

volts

a-946

large
thin
Leyden Jar

a-970

polarized

A·I·R ©1960

A-983

The equation for total capacitance of capacitors in ________ is $C_T = C_1 + C_2 + C_3$. The equation for the equivalent capacitance of capacitors in ________ is $\frac{1}{C_E} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

A-959

If air is used as the dielectric, the value of k will be 1. If glass is used, $ ____ will have a value of about 8, depending on the kind of glass.

A-935

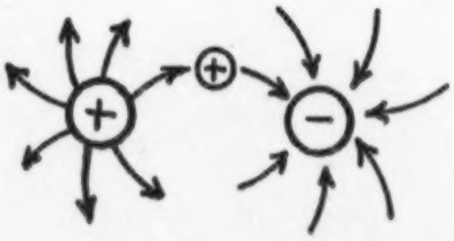
If we have several capacitors all with plates of the same size, the highest capacitance will be obtained from the capacitor which has its plates * ________ .

A-911

Electric field intensity times charge equals ________ or $ ____ .

A-887

This figure shows the lines of force caused by placing two charged objects near each other. A positive * ________ located somewhere between them will be influenced by both charged objects. It will be ________ by the positively charged object and ________ by the negatively charged object.



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A-875

An electric field also has direction, which is the direction of force on the one coulomb + test charge. If the test charge is attracted to the charged object, we know the charge on the object is ______, and the direction of the force is (toward/away from) ______ the object.

A-899

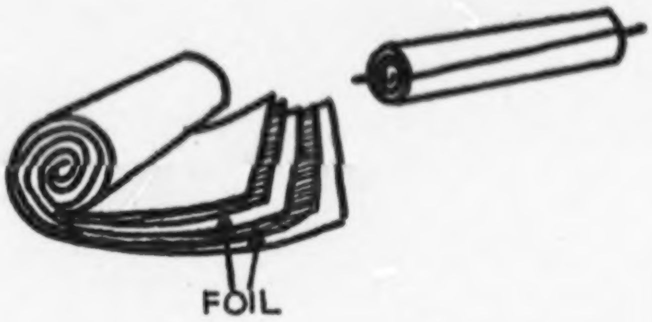
To compute the * ______ we can use the formula $E = k\frac{Q}{d^2}$. This formula will give us the correct value for E so long as the object creating the electric field is very small or a sphere. The more general law for electric field intensity is $ ______ $= \frac{F}{Q'}$.

A-923

The unit of measurement for capacitance is a farad. One ______ $= \frac{\text{one coulomb}}{\text{one volt}}$.

A-947

Capacitors are used in radios. Many of these use paper as the ______ between aluminum foil plates. The paper and foil are made into a sandwich and then rolled up as in Fig. 1. Since paper is used as the dielectric, the finished product which looks like that in Fig. 2 is known as a paper ______.



A-971

We can show that most of the energy stored by a capacitor is actually stored in the dielectric material by removing the dielectric from between the plates of a charged capacitor and inserting it between the plates of an uncharged capacitor. If we attach a voltmeter between the plates of the second capacitor, it will indicate a * ______ ______.

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a-982

$(\frac{1}{C_E} =)\ \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

---

a-958

dielectric

---

a-934

B

A

---

a-910

electric field intensity (or, intensity of the electric field)

E

force

---

a-886

lines of force

a-875

negative
toward

a-899

electric field intensity (or, intensity of the electric field)
E

a-923

farad

a-947

dielectric
capacitor

a-971

difference of potential (or, potential difference)

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A-982

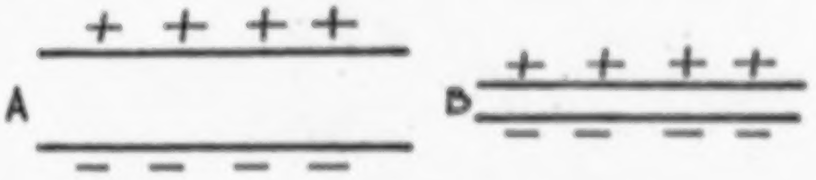
The formula for capacitors in series is $\frac{1}{C_E}$ = [\$].

A-958

ϵ_o, called the permittivity of a vacuum, is one constant used in the capacitance equation. The number is 8.85×10^{12}. The value of the constant k depends on the [ ] we use in the capacitor.

A-934

Capacitor [\$] will have a higher capacitance than capacitor [\$].

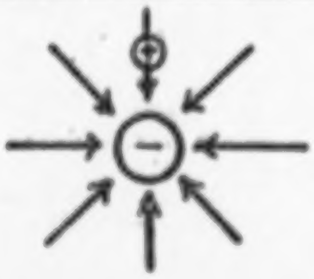


A-910

Dividing force by charge gives us the [*] or [\$]. In a uniform electric field, the [ ] on a + test charge will be the same no matter where the test charge is placed.

A-886

The lines showing the direction of force on a positive test charge are called lines of force. The figure shows [*] with an inward direction.



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A-876

An electric field has both intensity and direction at any point. Intensity tells us how strong the * ____________________ on a one coulomb + test charge is at any one point, and ____________ tells us whether a + test charge will move toward or away from the charged object.

A-900

The best way to define electric field intensity is to say it is equal to the force on the test charge divided by the size of the charge. The equation reads E = $ ______.

A-924

A farad is a very large unit of capacitance. A more convenient unit is the microfarad. A microfarad is one-millionth of a farad. We often abbreviate ____________ as mfd.

A-948

Another type of capacitor is called the variable capacitor. It has two sets of plates, one set within the other. Turning a knob rotates the inside set. This increases or decreases the plate area and therefore changes the ____________. It has a variable capacitance and is called a ____________ capacitor.

A-972

We represent a capacitor on a schematic diagram with two lines as in Fig. 1. If an arrow is shown, it means the capacitance can be varied.
Fig. 2, therefore, indicates a ____________ capacitor.

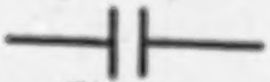

FIG. 1

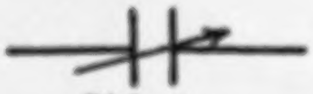

FIG. 2

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a-981

$$\left(\frac{1}{C_E} =\right) \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

a-957

constant
constants
different

a-933

higher
lower

a-909

F
newtons

a-885

direction
positive (+) test charge

A·I·R ©1960

a-876

force of attraction or repulsion
direction

---

a-900

$\frac{F}{Q'}$

---

a-924

microfarad

---

a-948

capacitance
variable

---

a-972

variable

A·I·R ©1960

A-981

The formula for capacitors in series is like that for resistors in parallel. To find the equivalent capacitance, we sum reciprocals in the formula:

$\frac{1}{C_E}$ = [\$].

A-957

In a formula, there sometimes is a number which always remains the same and this is known as a [ ]. In the formula $C = \epsilon_0 k \frac{A}{D}$, ϵ_0 and k are both [ ]. The number k will be (the same/different) [ ] for different materials which can be used as a dielectric.

A-933

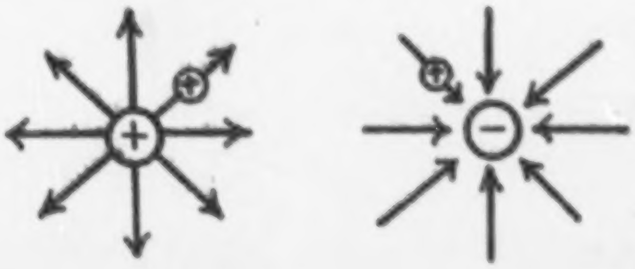
The closer the plates in a capacitor, the [ ] the capacitance. The farther the plates, the [ ] the capacitance.

A-909

If the electric field intensity, E, is known and the charge is known, we find the force by multiplying E x Q'; that is, [\$] = EQ', when E is in newtons/coulomb, (say, "newtons per coulomb"), Q' is in coulombs, and F, or force, is in [ ].

A-885

The electric fields around two charged objects are pictured below. Although the electric field cannot actually be seen, we draw these lines to make it easier to study the [ ] of force on a [*].



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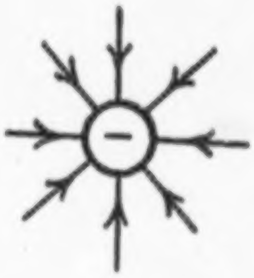
A-877

If a charged object has a negative charge, a positive test charge will be ______ to the object. The direction of the electric ______ will be inward.



A-901

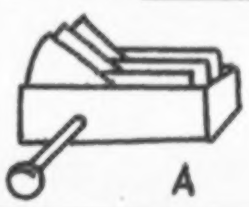
The two formulas for intensity of electric field are $E = \frac{F}{Q}$, and $E = k\frac{Q}{d^2}$. To use the first formula, we divide the * ______ by the * ______. The second formula means that for small objects and spheres, the intensity of their field at any point is equal to ** ______ ______.

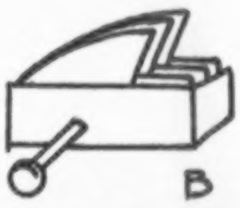
A-925

Mfd is the abbreviation for one-millionth of a farad, which is called a ______. The formula for capacitance is $C = \frac{Q}{v}$. In units of measurement this would be ______ = ______ / ______.

A-949

A variable capacitor is shown in the figure. In position A, the area of the plates where they overlap is greater than in position B. The capacitance in position $ ______ will therefore be greater than it would be in position $ ______.





A-973

Just like resistors, capacitors can also be connected in series and in parallel in a ______.

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a-980

(C_T =) $C_1 + C_2 + C_3$
area
dielectric

a-956

area of overlap of the plates
distance between the plates
capacitance

a-932

(C =) 2
decrease
(C =) 5
increase
decrease

a-908

E
$\frac{F}{Q'}$

a-884

repelled
positive (+) test charge
attracted

A·I·R ©1960

a-877

attracted
field

a-901

force (on the + test charge)
size of the test charge
a constant times the charge on the object, divided by the distance (between the test charge and the object) squared

a-925

microfarad

farad (or, microfarad, mfd) = $\frac{\text{coulombs}}{\text{volts}}$

a-949

A
B

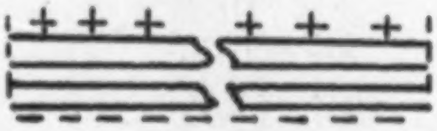
a-973

circuit

A·I·R ©1960

A-980

The formula for total capacitance for capacitors in parallel is $C_T = \boxed{\$ \qquad\qquad}$. This is easy to remember with an example. If we have a big capacitor and cut it in half, the two together still have the same plate $\boxed{}$, the same distance between plates, and material of the same $\boxed{}$ constant.



A-956

In the formula $C = \epsilon_o \, k \frac{A}{D}$, A is the $\boxed{* \qquad\qquad\qquad\qquad\qquad}$ measured in square meters. D is the $\boxed{* \qquad\qquad\qquad\qquad}$ measured in meters. C is the $\boxed{}$ in units called farads.

A-932

If a capacitor has 10 coulombs of charge, and the potential difference between the plates is 5 volts, the capacitance, $C = \boxed{\# \quad}$ farads. If we move the plates closer together, the voltage will $\boxed{}$, let's say to 2 v. Now, $C = \boxed{\# \quad}$ farads. Moving the plates closer will (increase/decrease) $\boxed{}$ the capacitance and (increase/decrease) $\boxed{}$ the voltage.

A-908

Charge is measured in units of coulombs, and force is measured in units of newtons, so the intensity or $\boxed{\$ \quad}$, of an electric field is measured in newtons per coulomb.

The formula is $E = \boxed{\$ \quad}$.

A-884

In Fig. 1, the direction of the electric field indicates the object has a positive charge. The arrows indicate that, no matter where it is placed, a + test charge will be $\boxed{}$. Fig. 2 shows the electric field for an object with negative charge. It indicates a $\boxed{* \qquad\qquad\qquad\qquad}$ will be $\boxed{}$ wherever it is placed.

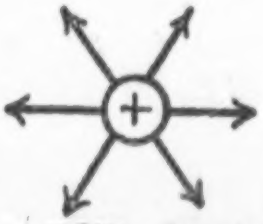


FIG. 1

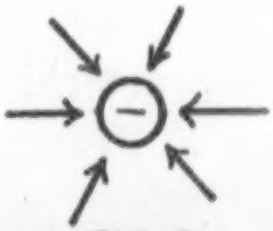


FIG. 2

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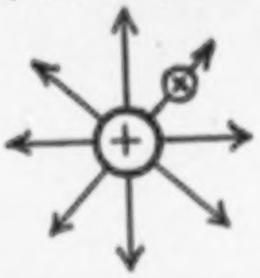
A-878

If a positive test charge is near a positively charged object, the charge will be (attracted/repelled) ________. The direction of the * ________ in this case will be outward.



A-902

A uniform electric field is one in which both the direction and intensity of the field is constant. Two charged metal plates, parallel to each other, will provide a ________ electric field. A charged object with an irregular shape, does not have a * ________.

A-926

A device which has capacitance is called a capacitor. Any electrical device which can store quantities of electricity can be called a ________.

A-950

The capacitance of a capacitor depends on three factors. These are the ** ________ ________ ________.

A-974

Fig. 1 shows ________ in ________. Fig. 2 shows ________ in ________.

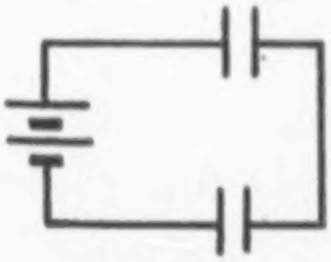


FIG. 1

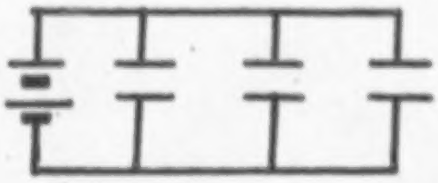


FIG. 2

A·I·R ©1960

a-979

$(C_T =)\ C_1 + C_2 + C_3$

a-955

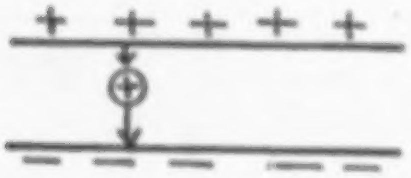
area of overlap
distance
dielectric

a-931

capacitance

a-907

uniform



a-883

repelled
direction
electric field
positive

A·I·R ©1960

a-878

repelled
electric field

a-902

uniform
uniform electric field

a-926

capacitor

a-950

area of overlap of the plates, distance between plates, and dielectric used

a-974

capacitors (in) series
capacitors (in) parallel

A·I·R ©1960

A-979

The formula for capacitors in parallel is similar to the formula for resistors in series. The values of each capacitor are added to find total capacitance. The formula would be C_T = ☐.

A-955

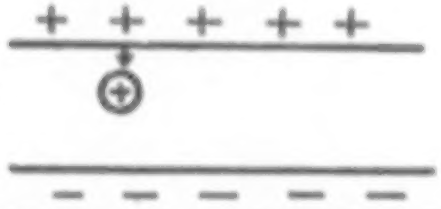
To determine the capacitance, we can use the formula $C = \epsilon_0 k \frac{A}{D}$, which gives us a calculation based on the ☐ * of the plates, the ☐ between them, and the substance being used as the ☐ in the capacitor.

A-931

In a parallel plate capacitor, the distance between the plates affects the capacitance. As the distance between the plates becomes less, the capacitance is increased. The greater the distance between the plates, the smaller will be the ☐.

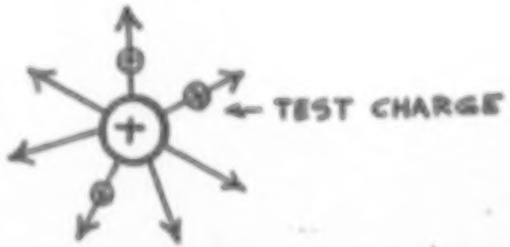
A-907

The force acting upon a + test charge will be of the same strength and in the same direction no matter where the + test charge is placed in a ☐ electric field. The figure shows an arrow indicating the force of repulsion on the test charge by the positive plate. Draw an arrow showing the force of attraction on it by the negative plate.



A-883

No matter where a positive test charge is placed near a positively charged object, it will be ☐. We can show this ☐ of the ☐ * by means of arrows. In this figure, we know the charged object must have a ☐ charge. The arrows point in the direction in which the + test charge will tend to move.



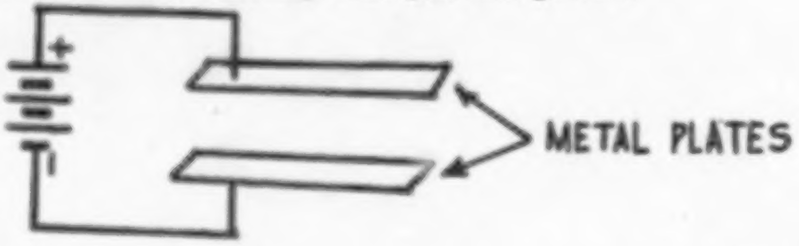
A·I·R ©1960

A-879

We always use a positive test charge when we are studying the direction and intensity of an * __________.

A-903

Two metal plates connected to the terminals of a battery will give one plate a __________ charge and the other plate a * __________.



A-927

If a capacitor has a charge of 4 coulombs and there is a potential difference of 2 volts between the plates, then $C = \frac{Q}{v}$ or $C = \frac{4}{2}$, C = # __________ farads. More usually, capacitors have higher voltages and smaller charges than this. If Q = .004 and v = 2000, C = 2 mfd, or 2 __________ of a farad.

A-951

To find capacitance, knowing charge and voltage, we would use the formula C = $ __________. The answer will be in units called __________.

A-975

Fig. 1 shows __________ in __________. Fig. 2 shows __________ in __________.

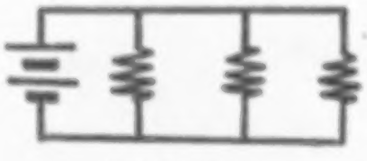


FIG. 1

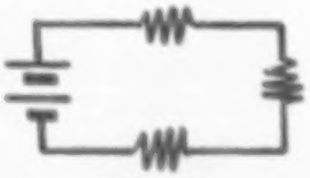


FIG. 2

A·I·R ©1960

a-978

$(R =)\ R_1 + R_2 + R_3$

$(\frac{1}{R_E} =)\ \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

---

a-954

constant of a vacuum
constant

---

a-930

A
B

---

a-906

uniform
uniform
the same anywhere between the plates

---

a-882

force
charge

A·I·R ©1960

a-879

electric field

a-903

positive (negative)
negative (positive) charge

a-927

2
millionths

a-951

$(C =) \frac{Q}{V}$

farads (or, microfarads, mfd)

a-975

resistors (in) parallel
resistors (in) series

A·I·R ©1960

A-978

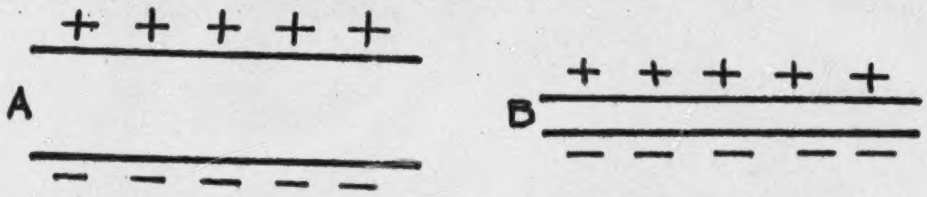
To find the total resistance of resistors in series, we use the formula R = [\$ ______]. To find the equivalent resistance of resistors in parallel, we use the formula $\frac{1}{R_E}$ = [\$ ______].

A-954

The symbol ϵ_o (say, EP-SI-LON NAUGHT; naught, by the way, means zero) stands for the permittivity [** ______]. ϵ_o is a constant for this equation, just as k was used as a [______] in Coulomb's Law.

A-930

The two capacitors in the figure both have the same amount of charge. The voltage of capacitor [\$ ___] will be higher than that of capacitor [\$ ___].



A-906

The electric field between two round objects will not be very [______] because the force will depend on where a test charge is placed in this field. The field between two parallel metal plates will be [______]; that is, the force will be [** ______].

A-882

An electric field exists wherever there is a [______] acting upon a test charge. Electric field intensity is defined as force per unit of [______].

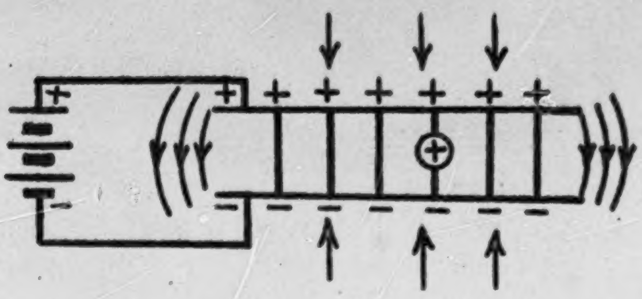
A·I·R ©1960

A-880

The direction of an electric field indicates the ☐ in which a + test charge will tend to move if brought near a charged object.

A-904

In the figure, two metal plates parallel to each other, have been connected to a battery. Between the plates there is a ☐ electric field. Near the ends, and outside the plates, however, the electric field is not ☐.



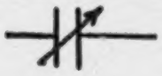
A-928

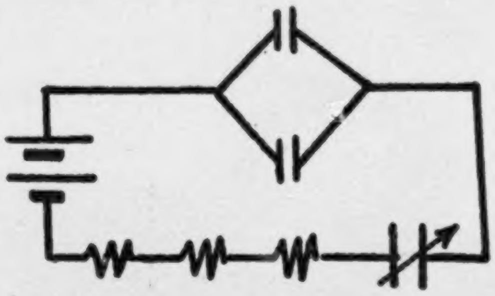
If opposite charges are placed on the plates of a capacitor, we find that as we move the plates closer together, the voltage between the plates becomes smaller. Likewise, if we move the plates farther apart, the voltage will be (increased/decreased) ☐.

A-952

For capacitors made from parallel plates, capacitance can be computed if we know the area of overlap of the plates in square meters (A), the distance between the plates in meters (D), and the dielectric constant (k). The dielectric constant is a number which indicates how good a dielectric a particular material is. For any one kind of material, k is constant; that is, it is always (the same/different) ☐.

A-976

This figure shows three ☐ in ☐, two ☐ in ☐, and a ☐* indicated by the symbol .



A·I·R © 1960

a-977

resistances for each resistor
resistances for each resistor

a-953

area of overlap of the plates
distance between the plates
constant
dielectric constant

a-929

smaller
larger

a-905

attracted
negative

a-881

positive test charge (or, small positive charge)
intensity

A·I·R ©1960

445

a-880

direction

a-904

uniform

uniform

a-928

increased

a-952

the same

a-976

resistors (in) series

capacitors (in) parallel

variable capacitor

A·I·R ©1960

A-977

For resistors in series, we sum the ** ______. For resistors in parallel, we work with the reciprocals of ** ______.

A-953

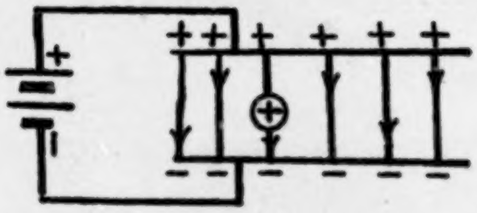
There are two formulas for capacitance, $C = \frac{Q}{V}$ and $C = \epsilon_0 k \frac{A}{D}$. In the second formula, A stands for * ______, D stands for * ______, and k stands for the dielectric ______. The symbol ϵ is the Greek letter "epsilon". The symbol ϵ_0 is called the permittivity constant of a vacuum. The part of the formula ϵ_0 k stands for this constant times the * ______ of the material being used.

A-929

If the amount of charge, in coulombs, on a capacitor remains the same, but we move the plates closer, the voltage will become ______. If we move the plates apart, the voltage becomes ______.

A-905

In the diagram, a positive test charge has been placed in the electric field. The charge is repelled by the positive plate, and ______ by the negative plate. There is a downward force acting on it. The direction of the electric field between these plates is toward the ______ plate.



A-881

The direction of an electric field indicates the direction in which a * ______ will tend to move if brought near a charged object. The ______ of the field indicates how much force is acting on a one coulomb + test charge placed at some point in the field.

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TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

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X (447)

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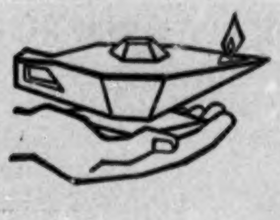
UNIT NINE

ELECTROSTATICS AND CURRENTS REVIEW

Steps A-986 through A-1147

Special Introductions

This is a Review Unit. It covers material you have had before. If you have difficulty with any section you should go back to a previous Unit, where you first learned that particular part of static or current electricity.



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BEGIN UNIT HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

TURN BOOK AROUND AND CONTINUE HERE

UNIT ENDS HERE

A-986

When electric charges are at rest we call this ________ electricity.

A-1030

If a negative rod touches a neutral object, the object gains a ________ charge. Repulsion will then occur because ** ________. When an object gains a charge by being touched with a charged object, this is called charging by ________.

A-1074

Whenever we connect an object with positive potential to an object with negative potential with a conductor, * ________.

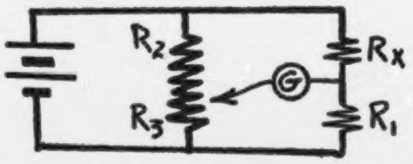
A-1118

To find volts, knowing current and resistance, we use the formula V = $ ________.

To find amps, knowing volts and ohms, we use the formula I = $ ________.

A-1162

A * ________ circuit is shown in the diagram. Before we compute the resistance of the unknown resistor, R_X, we adjust the slider until the ________ reads ________.



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a-1161

resistance
resistor

---

a-1117

voltmeter
ammeter
Ohm's
$(R =) \frac{V}{I}$

---

a-1073

volts

---

a-1029

neutral

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(463)

a-986

static

---

a-1030

negative

the rod and the object both have a negative charge (or, they both have like charges)

conduction

---

a-1074

current will flow

---

a-1118

$(V =) IR$

$(I =) \frac{V}{R}$

---

a-1162

Wheatstone Bridge

galvanometer

zero

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A-1161

We use a galvanometer in a circuit called the Wheatstone Bridge. A Wheatstone Bridge is used to measure the __________ of an unknown __________.

A-1117

To find the resistance of a circuit we could use a __________ to measure voltage, and __________ to measure current, and then apply __________ Law that,

$R = \dfrac{\boxed{\$\qquad}}{\boxed{\$\qquad}}$, to find the resistance.

A-1073

A voltmeter measures difference of potential in units called __________.

A-1029

If a charged object touches a neutral object, the neutral object will gain a charge. The object will then no longer be __________.

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A-987

Static electricity refers to electric ____ which are at ____.

A-1031

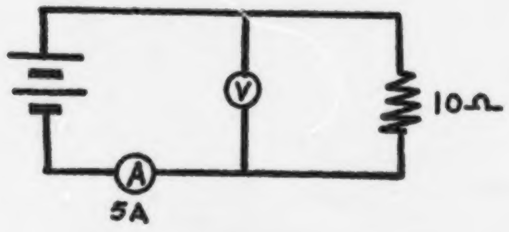
Charging by conduction means ** ____.

A-1075

Current can also flow between two objects which both have negative potential so long as there is a difference in the over-all concentration of ____ on the two objects.

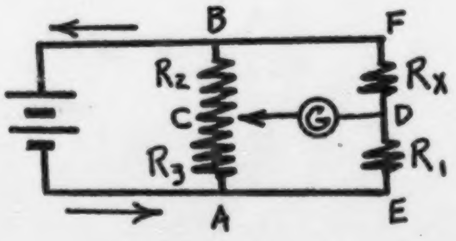
A-1119

A circuit having a resistance of 10 ohms and a current of 5 amperes has a voltage of * ____.



A-1163

When the galvanometer reads zero, we know the potential at points $ ____ and $ ____ are the same. When it reads zero, we also know that whatever current flows through R_3 must also flow through $ ____, and whatever current flows through R_1 must also flow through $ ____.



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a-1204

ability of an object to store electric charge

---

a-1160

current

ammeter

---

a-1116

11 ohms

---

a-1072

toward

electrons will flow away from object

---

a-1028

attraction or repulsion

distance

decreases

A·I·R ©1960

a-987

charges
rest

a-1031

placing a charge on (transferring a charge to) an object by touching it with a charged object

a-1075

electrons (or, charge)

a-1119

50 volts

a-1163

C (and) D
R_2
R_X

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A-1204

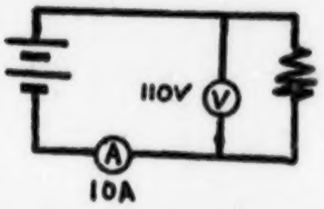
Capacitance is the ** ______________________________.

A-1160

A galvanometer is a device used to measure very small amounts of __________. A device used to measure larger amounts of current is called an __________.

A-1116

If a circuit has a voltage of 110 volts and the current in the circuit is 10 amperes, the resistance is * __________.



A-1072

Positive potential means electrons will flow (toward/away from) __________ the object. Negative potential means ** ______________________________.

A-1028

The attraction of a neutral object to a charged object illustrates that part of Coulomb's Law which states that the force of * ____________________ increases as the __________ between charges __________.

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A-988

If two charged objects pull at each other, that is, tend to move together, we call this a force of [ ]. If two charged objects push at each other; that is, tend to move apart, we call this a force of [ ].

A-1032

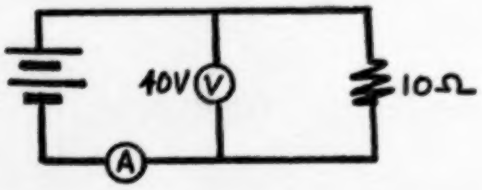
When we charge an object by induction, we do not [ ] the object with a charged object. When we charge by [ ], no charge is added but the charges in the object are redistributed.

A-1076

There is a potential difference between any two objects so long as there is a difference in the over-all [*] on the two objects.

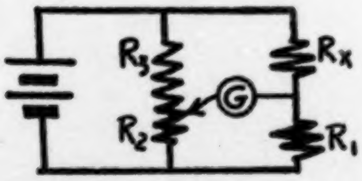
A-1120

A circuit having a resistance of 10 ohms and a voltage of 40 volts will allow a current of [*] to flow.



A-1164

When the galvanometer reads zero, we know that the IR drop across R_3 equals that across R_1, and that the [*] across R_2 equals that across [$].



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a-1203

electric field

a-1159

$(\frac{1}{R_E} = \frac{5}{6}, R_E = \frac{6}{5} =)$ 1.2 ohms

$(I = \frac{6}{1.2} =)$ 5 amps

a-1115

volt

ampere (or, amp)

ohms)= $\frac{\text{volts}}{\text{amperes}}$

a-1071

positive

negative

a-1027

polarization

shift (or, move)

like charges

attraction

A·I·R ©1960

(461)

a-988

attraction
repulsion

a-1032

touch
induction

a-1076

concentration of electrons (or, charge)

a-1120

4 amps

a-1164

IR drop
R_X

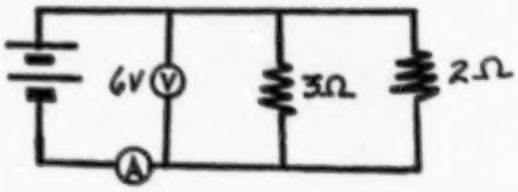
A·I·R ©1960

A-1203

A charged object is always surrounded by an *.

A-1159

The equivalent resistance in this circuit is *, and the total current flowing through the ammeter in this circuit is *.



A-1115

The unit of resistance is an ohm. The unit for voltage is the ☐ and the unit for current is the ☐. In units of measurement we can write Ohm's Law as

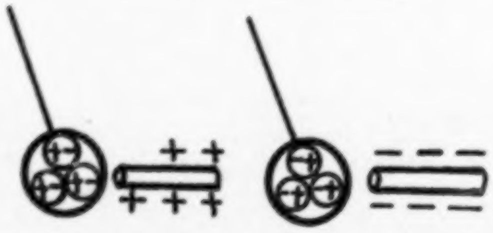
ohms = $\frac{\square}{\square}$.

A-1071

In physics, work can be positive or negative. When force is required to move an object, work is ☐. When force is required to keep an object from moving, work is ☐.

A-1027

A charged rod will attract a neutral insulator although the electrons are not free to leave their atoms. In this case, ☐ has occurred within each atom, which means electrons in the insulator ☐ inside their atoms. Unlike charges will then be closer to the charged rod than * ☐ and ☐ will tend to occur.



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A-989

Depending on the kind of charge, ______ electric charges can cause the pulling together, or ______ of objects, and the pushing apart, or ______ of objects.

A-1033

To charge by induction, we bring a charged rod near a conductor, as in Figure 1. While the rod is nearby, we separate the object, as in Figure 2. When we then remove the rod, the two parts of the object will both be ______. They will have (the same/opposite) ______ signs of charge.

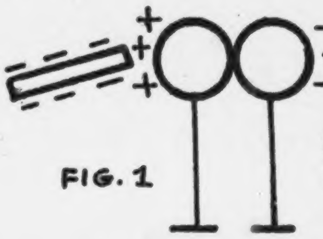


FIG. 1

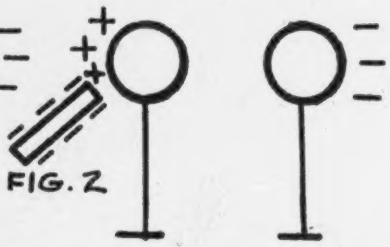


FIG. 2

A-1077

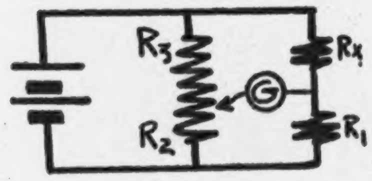
The over-all concentration of electrons on objects depends on the size of the objects, their shape, and the amount of charge on the objects. Current will flow between two objects when they are connected with a conductor so long as they differ in their * ______.

A-1121

Ohm's Law can be stated three ways, $ ______ to find resistance, $ ______ to find voltage, or $ ______ to find current.

A-1165

Since the current through R_2 is the same as that through R_3, and the current through R_1 is the same as that through R_X, we can write the IR drops as $I_1 R_3 = I_2 R_1$ and $I_1 R_2 =$ $ ______. If we divide one equation by the other we get $\frac{I_1 R_3}{I_1 R_2} =$ $ ______.



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a-1202

$$R = \frac{V}{I}$$

$$V = IR$$

$$I = \frac{V}{R}$$

a-1158

$$(I =) \frac{V}{R}$$

a-1114

$$\text{resistance} = \frac{\text{voltage}}{\text{current}} \quad \left(\text{or, ohms} = \frac{\text{volts}}{\text{amperes}}\right)$$

a-1070

$$\text{volts} = \frac{\text{joules}}{\text{coulombs}}$$

a-1026

the electrons (within the atoms of an insulator) shift toward one side of the atoms.

A·I·R ©1960

a-989

static
attraction
repulsion

a-1033

charged
opposite

a-1077

over-all concentration of electrons (or, charge)

a-1121

$R = \frac{V}{I}$

$V = IR$

$I = \frac{V}{R}$

a-1165

$I_2\,R_X$

$\frac{I_2\,R_X}{I_2\,R_1}$

A·I·R ©1960

A-1202

The three ways of expressing Ohm's Law are, $\boxed{\$\quad}$, $\boxed{\$\quad}$, and $\boxed{\$\quad}$.

A-1158

To find the total current flowing through a parallel circuit, we could find R_E, and then compute current by means of the formula I = $\boxed{\$\quad}$.

A-1114

The formula for finding resistance in a circuit is called Ohm's Law. Ohm found that R = $\frac{V}{I}$. In words, the formula reads $\boxed{} = \frac{\boxed{}}{\boxed{}}$.

A-1070

Our formula for volts is V = $\frac{w}{q}$. In units of measurement, this is $\boxed{} = \frac{\boxed{}}{\boxed{}}$.

A-1026

Polarization means that $\boxed{**\quad}$.

A·I·R ©1960

A-990

Objects having the same charge will ______ each other. Objects having unlike charges will ______ each other.

A-1034

Induction occurs when the charges in neutral conductors are redistributed as a * ______ is brought nearby. If the objects are allowed to touch, however, ______ will occur because the two objects will then have the same or ______ charges.

A-1078

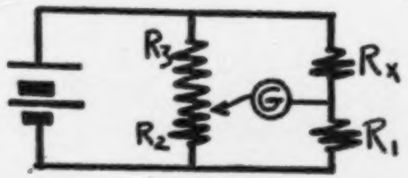
Current will flow from objects with a higher over-all concentration of electrons to objects with a * ______. This is the same as saying, current will flow from objects of ______ potential to objects of ______ potential if they are connected with a conductor.

A-1122

The potential difference measured at the source in an open circuit is called the e.m.f., or * ______. The potential difference measured across a closed circuit is the applied ______.

A-1166

Since $\frac{I_1 R_3}{I_1 R_2} = \frac{I_2 R_1}{I_2 R_X}$, we can "cancel," and get $\frac{R_3}{R_2} =$ $ ______. This formula for the Wheatstone Bridge circuit says that the proportion of R_3 divided by R_2 is equal to the proportion * ______.



A·I·R ©1960

a-1201

opposition (of a material) to the flow of current

a-1157

6 amps
4 amps
decreases

a-1113

opposition to the flow of current

a-1069

coulombs

(volts =) $\frac{\text{joules}}{\text{coulombs}}$

a-1025

insulators
free

896

A·I·R ©1960

469

a-990

repel

attract

a-1034

charged object

repulsion

like

a-1078

lower over-all concentration of electrons

higher

lower

a-1122

electromotive force

voltage

a-1166

$\frac{R_1}{R_X}$

R_1 divided by R_X

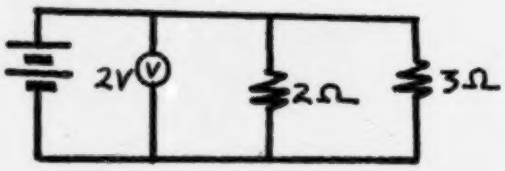
A·I·R ©1960

A-1201

Resistance is the ** ______________________.

A-1157

The current through the 2 ohm branch of this circuit is * ________, and through the 3 ohm branch it is * ________. As resistance increases, current ________.



A-1113

Resistance is an ** ______________________.

A-1069

Potential is calculated as the amount of work necessary to carry small + test charge to an object. Work is in units called joules and charge in units called ________. Potential equals work divided by charge, or, in units, volts= $\frac{\_\_\_\_\_\_}{\_\_\_\_\_\_}$.

A-1025

Electrons are not free to move from atom to atom in substances known as ________. When electrons are repelled in these materials, they shift within their atoms. This is called polarization. Polarization occurs when a charged object is brought near another object which has no ________ electrons.

A·I·R ©1960

A-991

The general rule for attraction and repulsion is that like charges [ ] while [**].

A-1035

A neutral object will still be [ ] when a charged body is brought near it. To give a neutral conductor a charge without touching it, we can connect it to the ground, then bring a [*], and then break the connection to the ground before withdrawing the charged object or rod.

A-1079

If electrons would flow from ground to a particular object, we know the object has a (higher/lower) [ ] potential than ground. If current would flow from some object to ground, we know that object has a (higher/lower) [ ] potential than ground.

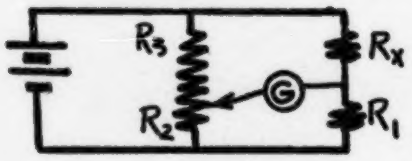
A-1123

The applied voltage is always less than the [*]. This difference in voltage is caused by the internal [ ] of the battery.

A-1167

To find the resistance of an unknown resistor in this circuit, we adjust the galvanometer to read zero and use the formula

[$] = [$].



A·I·R ©1960

a-1200

series
parallel

---

a-1156

resistance
branch
$(I =) \frac{V}{R}$
current in each branch

---

a-1112

resistance

---

a-1068

potential

---

a-1024

like
unlike

A·I·R ©1960

a-991

repel (each other)
unlike charges attract (each other)

a-1035

neutral
charged object (rod) near it

a-1079

lower
higher

a-1123

electromotive force
resistance

a-1167

$\frac{R_3}{R_2}$ (=) $\frac{R_1}{R_X}$

A·I·R ©1960

A-1200

To obtain a larger voltage, we can connect more than one cell in ☐. To obtain more current, we can connect several cells in ☐.

A-1156

The current through each branch of a parallel circuit depends on the ☐ in that ☐. To find the current through each branch, we use the Ohm's Law formula I = ☐ $. As stated by Kirchhoff's First Law, the total current in a parallel circuit equals the sum of the ☐ *.

A-1112

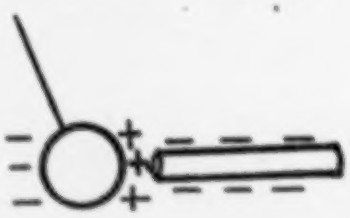
The opposition of a substance to the flow of current is called resistance. Conductors offer less ☐ than insulators.

A-1068

The unit of measurement for potential is a volt. When we speak of voltage we are referring to the difference of ☐ between two objects.

A-1024

A neutral conductor is attracted by a negative object because the object forces electrons to the far side of the neutral conductor, and the distance between (like/unlike) ☐ charges is then greater than between ☐ charges.



A·I·R ©1960

A-992

A charged rubber rod attracting fur is an example of the attraction of ☐ charges. Two charged rubber rods repelling each other is an example of the repulsion of ☐ charges.

A-1036

Induction is the process of ☐ ** .

A-1080

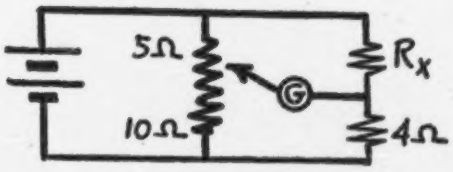
Current will always flow from objects with (positive/negative) ☐ potential to objects with (positive/negative) ☐ potential. Current will also always flow from objects with (higher/lower) ☐ potential to objects with (higher/lower) ☐ potential.

A-1124

Attaching a voltmeter to the terminals of a battery in an open circuit will give us the ☐ * . Attaching a voltmeter across a closed circuit will give us the ☐ * .

A-1168

In this figure, the galvanometer reads zero. The unknown resistor, R_X, produces a resistance of ☐ * .



A·I·R ©1960

a-1199

electrolyte

electrodes (or, anode and cathode)

chemical

electrical

a-1155

(always) the same

a-1111

6 volts

a-1067

there must be a difference of potential

connected with a conductor

a-1023

attracted

negatively

A·I·R ©1960

a-992

unlike
like

a-1036

charging an object without touching it (with a charged object).

a-1080

negative
positive
higher
lower

a-1124

electromotive force
applied voltage

a-1168

2 ohms

A·I·R ©1960

A-1199

If we drew a simple voltaic cell, we would show a container which held a liquid called the ________ and two metal strips called the ________. A battery converts ________ energy into ________ energy.

A-1155

The voltage across each branch of a simple parallel circuit is always the same. Regardless of the size of the resistors, and the number we have in a simple parallel circuit, the voltage across each one is * ________.

A-1111

Four 1.5 v cells in series will have a combined voltage of * ________.

A-1067

In order for current to flow ** ________ ________ between objects and the objects must be ** ________

A-1023

A neutral object will be attracted to a positively charged object. It will also be ________ to a ________ charged object.

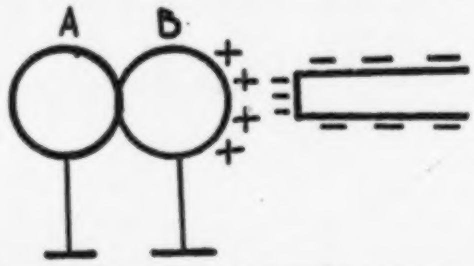
A·I·R ©1960

A-993

Physicists refer to charges as being positive or negative. Two positive charges will ______ each other. A positive charge and a negative charge will ______ each other. Two negative charges will ______ each other.

A-1037

When a negatively charged rod is brought near these two neutral metal balls which are touching each other, ball B will become temporarily ______ charged and ball A will become ______ charged. This is a step in the process called charging by ______.

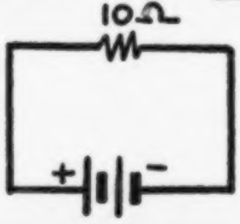


A-1081

A continuous supply of electrical energy can be obtained from a battery. A ______ converts chemical energy into ______ energy.

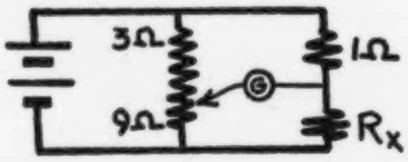
A-1125

The circuit below includes a resistance. It is labeled to indicate a resistance of * ______. An object which opposes the flow of current is called a ______.



A-1169

It makes no difference where the unknown resistor is; we still make a proportion of each branch of the circuit. In this figure, the unknown resistor produces a resistance of * ______.



A·I·R ©1960

a-1198

ground
toward
greater concentration of electrons

---

a-1154

$(\frac{1}{R_E} = \frac{5}{2}, R_E = \frac{2}{5} =)$ .40 ohms

---

a-1110

applied voltage
applied voltage

---

a-1066

negative potential
positive potential
difference of potential

---

a-1022

$$F = k \frac{QQ'}{d^2}$$

A·I·R ©1960

481

a-993

repel
attract
repel

a-1037

positively
negatively
induction

a-1081

battery
electrical

a-1125

10 ohms
resistor

a-1169

3 ohms

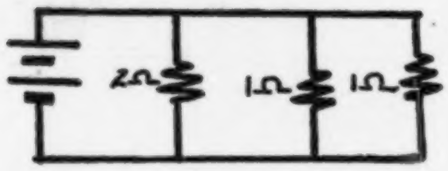
A·I·R ©1960

A-1198

An object is said to have potential in relation to ☐ which has a zero potential. Positive potential means that electrons will flow (toward/away from) ☐ the object from the ground. If one object has a higher potential than another, it means the object has a *

A-1154

The equivalent resistance in this circuit is * .

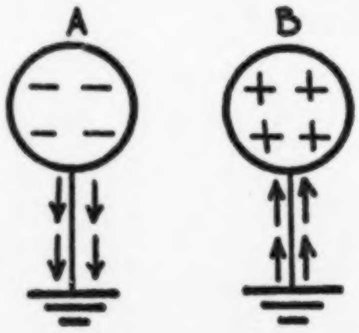


A-1110

Ordinarily when we talk about the voltage of a circuit, we mean the * ☐. The * is always less then the e.m.f.

A-1066

Object A has * . Object B has * . There is a * between them.



A-1022

The formula for Coulomb's Law is $.

A·I·R ©1960

A-994

An atom consists of a nucleus which has a [ ] charge and several [ ] around it which are [ ] charged.

A-1038

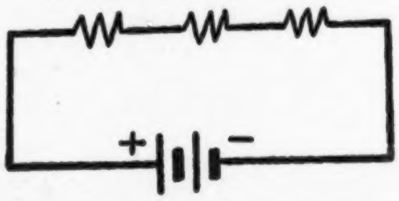
When we charge by induction, the object is not touched, and no [ ] is added to it from the charged source. When we charge by conduction, however, the object is [ ] and [ ] is added to it from the source.

A-1082

Batteries consist of one or more units called cells. One type of cell, based on the work of Volta, is called a [*].

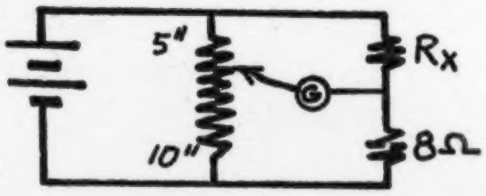
A-1126

Resistors can be connected in series. All the [ ] will flow through [*] [ ]. The diagram shows three [ ] in [ ].



A-1170

We can also use a proportion of lengths of resistors in the Wheatstone Bridge circuit to find the resistance of an unknown resistor. In this figure, R_X has a resistance of [*].



A·I·R ©1960

a-1197

a difference of potential

a-1153

$(\frac{1}{R_E} = \frac{8}{6},\ R_E = \frac{6}{8} =)$ .75 ohms

a-1109

applied

a-1065

ground to the object
positive potential

a-1021

coulombs
newtons
meters
constant

A·I·R ©1960

485

a-994

positive
electrons
negatively

---

a-1038

charge
touched
charge

---

a-1082

voltaic cell

---

a-1126

current
each (every) resistor
resistors
series

---

a-1170

4 ohms

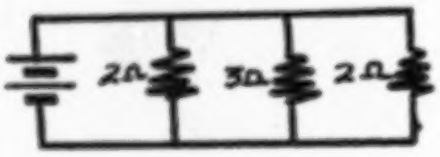
A·I·R ©1960

A-1197

In order to have an electric current it is necessary to have _____*_____.

A-1153

The equivalent resistance in this circuit is _____*_____. Remember, you have to find R_E and not $\frac{1}{R_E}$.



A-1109

When we talk about the electrical energy produced by a battery, we talk about the e.m.f. When we talk about the potential difference as measured in the circuit, however, we speak of it as the __________ voltage.

A-1065

When a positively charged object is connected to ground, electrons will flow from _____*_____. Before being connected, the object had _____*_____.

A-1021

In Coulomb's Law, Q and Q' are measured in __________, F is measured in __________, and d is measured in __________. The symbol k stands for a __________

A·I·R ©1960

A-995

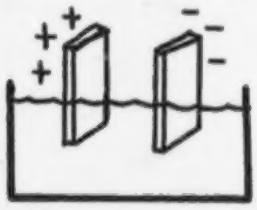
When we speak of the movement of charge along a conductor, we only refer to the movement of the ☐ charged ☐. Positive charges (do/do not) ☐ move in a conductor.

A-1039

To charge an object by conduction we ☐ ** .

A-1083

A voltaic cell consists of dilute acid called the electrolyte, and two metal plates called the electrodes. One electrode becomes ☐ charged, the other becomes ☐ charged.



A-1127

The total voltage across a series circuit is found by the formula $V_T = V_1 + V_2 + V_3$; that is, the total voltage is the ☐ of the individual voltages. In the symbol form the total applied voltage is indicated as ☐ $.

A-1171

The force of attraction or repulsion about a charged object is described as an electric ☐. A test charge will be attracted or ☐ if it is in a charged object's ☐ * .

A·I·R ©1960

a-1196

flow of electrons along a conductor

a-1152

resistance

$\left(\frac{1}{R_E} =\right) \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

a-1108

negative terminal of one cell to positive terminal of another, and so forth
sum of the e.m.f.'s of the cells

a-1064

the object to ground
negative

a-1020

force
charge
distance

A·I·R ©1960

a-995

negatively
electrons
do not

---

a-1039

touch it with a charged source (or, rod)

---

a-1083

positively (negatively)
negatively (positively)

---

a-1127

sum
V_T

---

a-1171

field
repelled
electric field

A·I·R ©1960

A-1196

An electric current is the ** ________.

A-1152

In a parallel circuit, only part of the current passes through each branch. We can find the R_E or equivalent ________ by using the reciprocals of the resistances. The formula is $\frac{1}{R_E}$ = $ ________.

A-1108

To connect cells in series, we must connect ** ________. The total e.m.f. is equal to ** ________.

A-1064

When a negatively charged object is connected to ground, electrons will flow from ** ________. Before being connected, the object could be described as having ________ potential.

A-1020

In Coulomb's Law, newtons are the unit of ________, coulombs are the unit of ________, and meters are the unit of ________.

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(491)

A-996

An object containing an equal number of positive and negative charges is a ______ object. An object with more electrons than positive charges is a * ______ object. An object with less electrons than positive charges is a * ______ object.

A-1040

The difference between charging by induction and charging by conduction is that ** ______.

A-1084

The chemical process in a cell causes ionization; that is, the molecules break up into charged fragments called ______. In a battery, such as a voltaic cell, this causes one electrode to be ______ charged and the other ______ to be ______ charged.

A-1128

The sum of the resistances of a series circuit, or $R_1 + R_2 + R_3$, is equal to R_T, the * ______ of a series circuit.

A-1172

The intensity of an electric field describes the ______ of the force of attraction or repulsion about a charged object. The nearer a test charge is to a charged object, the ______ is the intensity of the electric field at that point.

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a-1195

the charge on the objects

the distance between the objects

$F = k \frac{QQ'}{d^2}$

---

a-1151

B

every part (resistor) in the circuit

A

every part (resistor, branch) in the circuit

---

a-1107

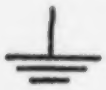
cells

electromotive force

---

a-1063

zero



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a-1019

$F = k \frac{QQ'}{d^2}$

force equals a constant times the product of charges (on the object) divided by square of the distance (between them)

A·I·R ©1960

493

a-996

neutral
negatively charged
positively charged

a-1040

objects charged by induction are not touched while objects charged by conduction are touched by a charged source.

a-1084

ions
positively (negatively)
electrode
negatively (positively)

a-1128

total resistance

a-1172

strength (or, intensity)
greater (or, stronger)

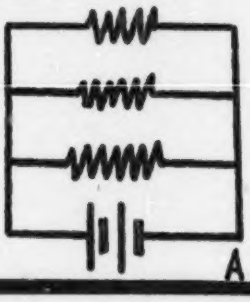
A·I·R ©1960

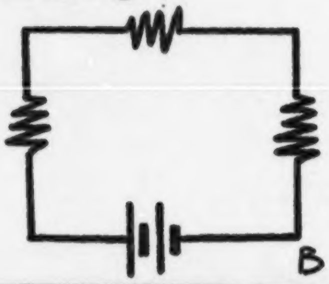
A-1195

Coulomb's Law says that we can increase electrostatic force by increasing ** or by decreasing ** . The formula for Coulomb's Law is $.

A-1151

A series circuit is shown in Figure $; all the current passes through * . A parallel circuit is shown in Figure $; all the current does not pass through ** .


A


B

A-1107

The total voltage of a 3-cell storage battery is 6 volts; the sum of the e.m.f.'s of the is the total e.m.f.; that is, the * .

A-1063

Objects are said to have negative or positive potential in relation to ground which is at potential. The symbol for ground is $.

A-1019

The formula for Coulomb's Law is $. It says that **

A·I·R ©1960

A-997

Only the free electrons in an atom will move to another atom. The movement of electrons refers only to the movement of [*].

A-1041

If charge is added to an insulator by conduction, the charge will not be distributed over the object but will remain [*].

A-1085

The positive electrode in a cell is called the anode. The negative electrode is called the cathode. These are inserted into a dilute acid called the [ ].

A-1129

The total voltage across a series circuit is found by the formula V_T = [$]. The total resistance in a series circuit is the sum of resistances, or R_T = [$].

A-1173

An electric field has both intensity and [ ]. The intensity of the field is defined as force per coulomb of test charge, or E = [$]. The direction of the field means whether a unit + test charge will be [ ] or [ ].

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a-1194

two unlike charges (or, a positive and a negative charge)
two like charges (or, two positive charges, two negative charges)

---

a-1150

does not

---

a-1106

positive (negative)
negative (positive)

---

a-1062

ground
zero

---

a-1018

force
a constant
charges on the objects
distance between the charges

A·I·R ©1960

a-997

free electrons

a-1041

at the point of contact (or, where the charge was added)

a-1085

electrolyte

a-1129

$(V_T =)\ V_1 + V_2 + V_3$

$(R_T =)\ R_1 + R_2 + R_3$

a-1173

direction

$(E =)\ \frac{F}{Q'}$

attracted (repelled)

repelled (attracted)

A·I·R ©1960

A-1194

Attraction occurs between ☐ ** .
Repulsion occurs between ☐ ** .

A-1150

In a parallel circuit, all the current (does/does not) ☐ flow through all parts of the circuit.

A-1106

An automobile battery is an example of cells connected in series; that is, the ☐ terminal of the first cell is connected to the ☐ terminal of the second cell, and so on.

A-1062

The symbol ⏚ stands for ☐ which is always at ☐ potential.

A-1018

The mathematical statement of Coulomb's Law is $F = k \frac{QQ'}{d^2}$. In it, F stands for ☐ , k is ☐ * , Q and Q' are the ☐ * and d^2 is the square of the ☐ * .

A-I-R ©1960

A-998

Substances which take free electrons from other substances are said to have an electron affinity. A substance gaining electrons because of its * ______ will gain a ______ charge.

A-1042

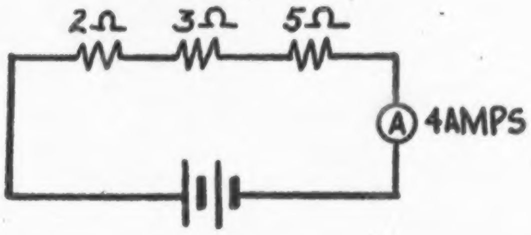
When a conductor receives a charge, the charge ** ______ ______.

A-1086

A battery cell consists of three parts, two metal plate electrodes which are called the ______ and ______, and an ______.

A-1130

If the resistances in a series circuit are known, and the current is known, we can fine the applied voltage by using ______ Law that V = IR. The total applied voltage in this circuit is * ______.



A-1174

The direction of an electric ______ is indicated by the direction in which a positive test charge will move if placed at some point in the ______. If the object producing the electric field is positively charged, the direction of the field will be (inward/outward) ______; if the object is negatively charged, the direction will be (inward/outward) ______.

A·I·R ©1960

a-1193

electric charges at rest (which are not moving)

---

a-1149

potential
greater

---

a-1105

6 (volts)

---

a-1061

difference of potential (or, potential difference)

---

a-1017

Coulomb's
force
charge
distance

A·I·R ©1960

a-998

electron affinity
negative

a-1042

is distributed over the conductor (or, object)

a-1086

anode (cathode)
cathode (anode)
electrolyte

a-1130

Ohm's Law
40 volts

a-1174

field
electric field
outward
inward

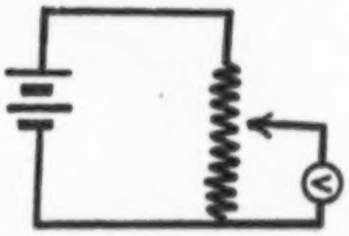
A·I·R ©1960

A-1193

Static electricity refers to ** .

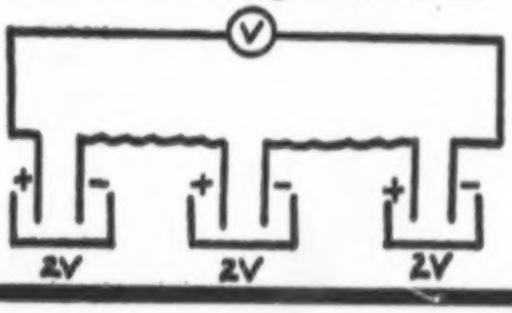
A-1149

By adjusting the slider on a divider, we obtain different voltages. The greater the length of the resistance we use, the (greater/smaller) the voltage.



A-1105

In a series circuit, the total voltage of the circuit is equal to the sum of the voltages for each cell. In the figure, the voltmeter will read # volts.



A-1061

Current will only flow when there is a * between objects.

A-1017

$F = k\frac{QQ'}{d^2}$ is the formula for Law. It says the of attraction or repulsion is equal to a constant times the product of the divided by the square of the .

A·I·R ©1960

A-999

A rubber rod has a stronger electron affinity than fur. When the rod is rubbed against the fur, the rod gains a [ ] charge. The fur loses [ ] and becomes [ ] charged.

A-1043

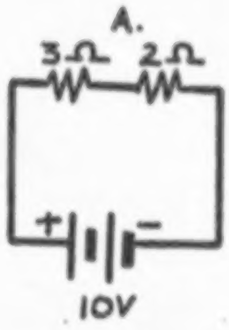
The distribution of charge on a conductor depends on the shape of the conductor. The charges on a sphere will be [*].

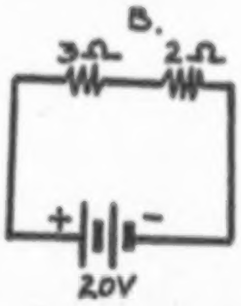
A-1087

We now use two kinds of batteries, both based on the principle of the voltaic cell. One uses a liquid electrolyte. It is called a [ ] cell battery. If a paste electrolyte is used, we call the battery a [*].

A-1131

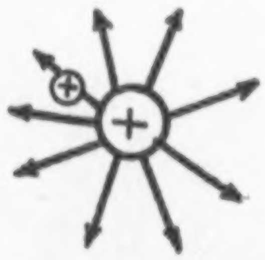
We can find the current flowing through a circuit with the formula $I = \frac{V}{R}$. Figure A has a current of [*]. Figure B has a current of [*].





A-1175

In this figure, the lines and arrows indicating the direction of the electric field are called [*].
They show the direction of force on a small [*].



A·I·R ©1960

a-1192

$(\frac{1}{C_E} = \frac{1}{12} + \frac{3}{12} + \frac{2}{12} =)\ \frac{6}{12}$ (or, $\frac{1}{2}$)

(C_E =) 2 m.f.d. (microfarads)

a-1148

resistance

divider

a-1104

positive

series circuit

a-1060

conductor

difference

a-1016

increases

decreases

A·I·R ©1960

506

a-999

negative
electrons
positively

a-1043

evenly distributed

a-1087

wet
dry cell battery

a-1131

2 amps
4 amps

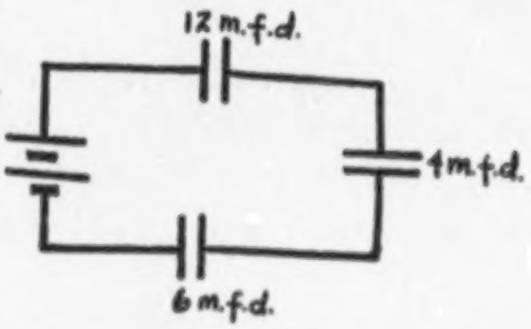
a-1175

lines of force
positive test charge

A·I·R ©1960

A-1192

In this circuit, $\frac{1}{C_E}$ = $\boxed{\#}$ m.f.d.'s and C_E = $\boxed{*}$.



A-1148

To change current we adjust ☐ when a single voltage source is available. We can obtain a variable source of voltage, however, by using a potential ☐.

A-1104

A number of cells can be connected in series. To connect them in series, the negative terminal of one cell is connected to the ☐ terminal of another. A circuit in which all the current flows through every part is called a $\boxed{*}$.

A-1060

Current will only flow when two objects with unequal concentrations of charge are connected by a ☐. This unequal distribution causes a ☐ of potential to exist.

A-1016

According to Coulomb's Law, increasing the amount of charge on either of the two objects ☐ the force of attraction or repulsion between them. Increasing the distance between them ☐ the force.

A·I·R ©1960

A-1000

An electroscope is a device used to detect the presence of an electric $\boxed{}$ on an object. We can also use an $\boxed{}$ to find whether the charge is negative or $\boxed{}$.

A-1044

The region of greatest concentration of charge on a conductor is at the place of greatest curvature. In Fig. 1, the area of greatest concentration of charge will be at $\boxed{\$}$ and $\boxed{\$}$; in Fig. 2, it will be at $\boxed{\$}$.

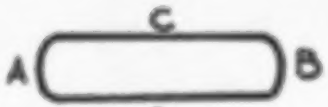


FIG. 1

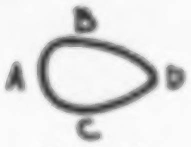


FIG. 2

A-1088

The battery used in flashlights and portable radios is of the $\boxed{*}$ type. This type usually has a voltage of about 1.5 volts in each $\boxed{}$.

A-1132

For a circuit with a given voltage, increasing the resistance in the circuit will $\boxed{}$ the current in the circuit.

A-1176

We can compute the intensity of the electric field at any point around a small object or sphere by using Coulomb's Law to compute force in the equation $E = \frac{F}{Q'}$. We then get $E = k\frac{Q}{d^2}$ which means, in words, $\boxed{**}$.

A·I·R ©1960

a-1191

$\left(\frac{1}{C_E} =\right) \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

---

a-1147

current

---

a-1103

closed
open
closed

---

a-1059

5 amperes (or, 5 amps)

---

a-1015

Coulomb's
electrostatic force

A·I·R ©1960

a-1000

charge
electroscope
positive

a-1044

A (and) B
D

a-1088

dry cell
cell

a-1132

decrease

a-1176

intensity of the electric field at any point (around a small object or sphere) equals a constant time the charge on the object divided by the distance between the object and the point squared.

A·I·R ©1960

A-1191

To find the equivalent capacitance of several capacitors in series, we use reciprocals in the formula $\frac{1}{C_E}$ = ______.

A-1147

Most circuits have a fixed voltage. The effect of varying the amount of resistance in such a circuit would therefore be on the amount of ______ flowing through it.

A-1103

A switch opens and closes a circuit. When the light is on, we know the circuit is ______. When the light is off, the circuit is ______. Current only flow through a ______ circuit.

A-1059

If 15 coulombs pass a given point in 3 seconds, the current is * ______.

A-1015

The force of attraction or repulsion between two charged objects is computed by means of ______ Law, that is, the law of * ______.

A·I·R ©1960

A-1001

An electroscope has two uses: to find if an object has received a ______ and to determine ** ______.

A-1045

A conductor sharpened to a point will have the greatest concentration of charge at the ______. The concentration of charge may be great enough to force some ______ into the air. This is called an electrical discharge. An * ______ occurs whenever the concentration of charge is so great that ______ are forced from a charged object.

A-1089

Batteries which can be recharged are called storage batteries. Automobile batteries are the kind known as * ______. They usually have a voltage of 2.0 volts per cell.

A-1133

An IR drop means the reduction in ______ as current passes through a ______.

A-1177

Another way of stating the formula which defines the intensity of the electric field is, intensity equals newtons per coulomb of test charge. Newtons are the units of ______, coulombs are the units of ______. The formula, in symbols, is $ ______.

A·I·R ©1960

a-1190

36

a-1146

current

a-1102

C

a-1058

$I = \frac{q}{t}$

current equals charges per second (or, amperes equals coulombs per second)

a-1014

force

force

A·I·R ©1960

a-1001

charge
the sign of the charge (or, whether the charge is positive or negative)

a-1045

point
electrons
electrical discharge
electrons

a-1089

storage batteries

a-1133

voltage
resistance (or, resistor)

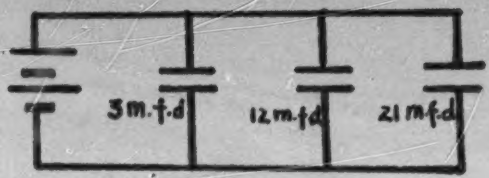
a-1177

force
charge
$E = \frac{F}{Q'}$

A·I·R ©1960

A-1190

The total capacitance in this circuit is # m.f.d.'s.

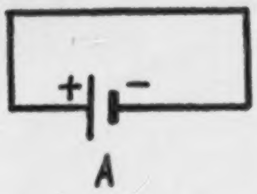


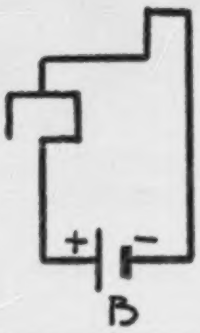
A-1146

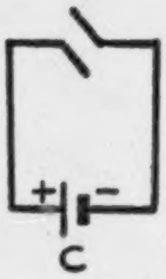
The voltage being applied to a circuit will not change if we add more resistance, but there will be a reduction in ______.

A-1102

Current will not flow in an open circuit.
In Figure $ current will not flow.


A


B


C

A-1058

The formula we use for current is $. In words we say, ** ______ ______.

A-1014

The amount of "push" causing objects to come together or move apart is called the force of attraction or repulsion. A statement of the ______ of attraction or repulsion between two charged objects is Coulomb's Law, the law of electrostatic ______.

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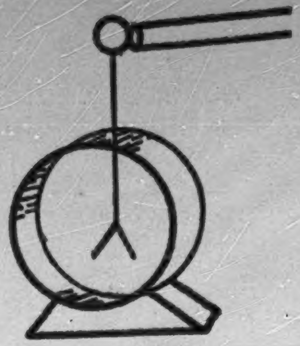
(915)

A-1002

If an object is touched to the knob of an electroscope and the leaves fly apart we know the object does have an [*]



A-1046

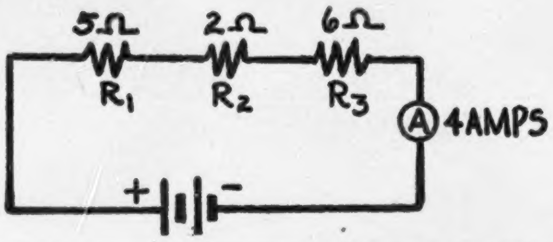
The ground is always considered electrically [ ]. When we ground a charged conductor, we [*].

A-1090

There are two kinds of batteries, the [*] and the [*]. The type of [ ] cell battery which can be recharged is called a [*].

A-1134

In the circuit below the IR drop across R_1 is [*]. Across R_2 it is [*], and across R_3 it is [*].



A-1178

A uniform electric field is one in which both the [ ] and [ ] of the field is constant. If two charged metal plates are placed parallel to each other, there will be a [*] between them.

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a-1189

sum (or, add)
$(C_T =)\ C_1 + C_2 + C_3$

---

a-1145

2 (inches)

---

a-1101

does not (will not) flow

---

a-1057

current
amperes

---

a-1013

electrons
flow of electrons

A·I·R ©1960

517

a-1002

electric charge

a-1046

neutral
touch it to ground (or, the earth)

a-1090

dry (wet) cell
wet (dry) cell
wet
storage batteries

a-1134

20 volts
8 volts
24 volts

a-1178

direction (intensity)
intensity (direction)
uniform electric field

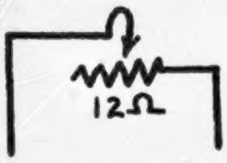
A·I·R ©1960

A-1189

To find the total capacitance for a circuit with several capacitors in parallel, we ______ the capacitances of each branch, or, C_T = $ ______.

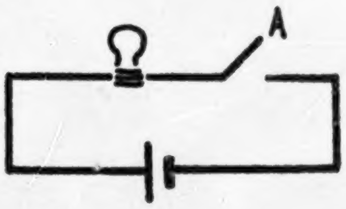
A-1145

In this circuit the variable resistor is six inches long and produces a maximum of 12 ohms resistance. To obtain a resistance of 4 ohms we would use # ______ inches of the resistor.



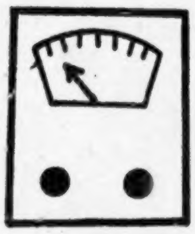
A-1101

The figure shows a circuit in which we have placed a switch. If we "open" the switch at A, we prevent current from flowing through the circuit. The lamp in an open circuit will not light because current * ______.



A-1057

An instrument called an ammeter is used to measure ______ in units called ______.



A-1013

If a positively charged object is touched to a conductor, the ______ in the conductor will be attracted to the object and this will start a * ______ toward the positively charged object.

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A-1003

To find the sign of a charged object, we first touch the electroscope with an object of known sign. Then we bring the object of unknown sign near the knob of the electroscope. If the leaves fly farther apart, the two objects have * ____________; if the leaves come together, they have * ____________.

A-1047

Lightning is an example of a very rapid * ____________. We can prevent lightning by using a lightning rod. This device, which is attached to the ________, neutralizes the positively charged air around it by ** ________________________.

A-1091

Electromotive force is the difference in ____________ produced by the chemical action in a battery. To measure e.m.f., or * ____________ we attach an instrument called a * ____________ to the terminals.

A-1135

Kirchhoff's Second Law states that the total applied voltage, or $V_T = V_1 + V_2 + V_3$. If the IR drops across three resistors in a series are 10 v, 4 v, and 6 v, the applied voltage must be * ________.

A-1179

Since one newton per coulomb equals one volt per meter, we can also write the formula for intensity of an electric field in terms of volts and distance or, in symbols, E = $ ______.

This formula is used to measure intensity of a ____________ electric field.

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a-1188

polarized
shift (to one side) within their atoms

---

a-1144

10 ohms

---

a-1100

closed

---

a-1056

current
amperes
charge
coulombs

---

a-1012

repel the electrons in the conductor causing them to move
supply of electrons (negative charge) at one end of a conductor
means of escape at the other end

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a-1003

the same charge (or, like charges)
opposite charges (or, unlike charges)

a-1047

electrical discharge
ground
discharging electrons (concentrated at its point) into the air

a-1091

potential
electromotive force
voltmeter

a-1135

20 volts

a-1179

$(E =) \frac{V}{d}$
uniform

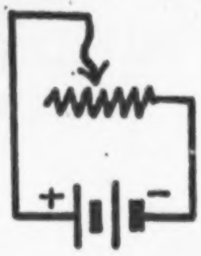
A·I·R ©1960

A-1188

As charges are applied to the plates of a capacitor, the dielectric material becomes __________, that is, the electrons * __________________________.

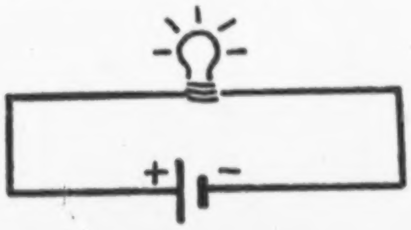
A-1144

In the circuit there is a variable resistor. The maximum resistance is 20 ohms. In this case, the resistance produced at the mid-point will be * __________.



A-1100

In electricity, we "close" a circuit by furnishing a path made of some conducting material so that current will flow. In the drawing, the lamp will burn continuously because the circuit is __________.



A-1056

$I = \frac{q}{t}$ is the formula for current. I stands for __________, measured in __________, q for __________, measured in __________, and t for time, measured in seconds.

A-1012

An electric current starts when a negative object is touched to a conductor because the electrons in the object ** __________________________. Current will continue to flow so long as there is a continuous ** __________________________ and a ** __________________________.

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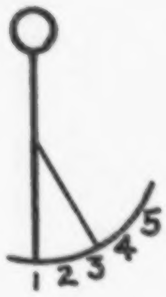
(523)

A-1004

Substances may be classified according to their ability to conduct electric charge. A substance which easily allows a charge to move through it is called a ______. A ______ has many ______ electrons.

A-1048

The difference between an electroscope and an electrometer is that there is a scale and only one gold leaf in an ______.



A-1092

The materials used in making batteries determine the amount of voltage available. The size of a battery (will/will not) ______ affect the voltage.

A-1136

Kirchhoff's Second Law states that the applied voltage of a series circuit or V_T equals $ ______. In words the formula is ** ______.

A-1180

If two charged metal plates are placed .2 meters apart, and have a potential difference of 60 volts, the intensity of the * ______ between them is # ______ volts per meter or # ______ newtons per ______.

A·I·R ©1960

a-1187

dielectric
dielectric constant

a-1143

length

a-1099

current
circuit

a-1055

(ampere =) $\frac{\text{coulombs}}{\text{second}}$

a-1011

conductor

A·I·R ©1960

525

a-1004

conductor
conductor
free

a-1048

electrometer

a-1092

will not

a-1136

$(V_T =)\ V_1 + V_2 + V_3$

The applied voltage of a series circuit equals the sum of voltages across each part (resistor)

a-1180

electric field
12
12
coulomb

A·I·R ©1960

A-1187

Most of the energy stored in a capacitor is actually stored in the ☐. Various materials differ in this ability. The relative ability of each material is indicated by its k, or ☐*.

A-1143

A variable resistor is made so that resistance can be adjusted. The kind of material and thickness remain constant. The resistance of this kind of device is varied by changing its ☐.

A-1099

A circuit is the path along which electric ☐ will flow. Conductors, but not insulators, can be used to make a ☐.

A-1055

Current is measured in amperes, charge in coulombs and time in seconds. We can then say, amperes = $\frac{\square}{\square}$

A-1011

Only conductors have electrons which are free to move from atom to atom. Therefore, a free flow of electrons is only possible in a ☐.

A·I·R ©1960

A-1005

Conductors are materials which ** ______________________.

A-1049

A proof-plane is a device, like the one shown in the figure, which is used to sample the charge on charged objects. To test for the presence of charge on an object, we sample the charge with a ____________ and then touch the ____________ to a device known as a ____________.

A-1093

The size of a battery affects the current but not the ____________. The size of the plates, however, does determine the amount of ____________.

A-1137

Every material, including wire produces some resistance to current. When we study circuits, however, we assume there is no resistance in a circuit unless it is indicated by the symbol $ ______.

A-1181

Capacitance is the ability to ____________ electric charge. Two charged metal plates will have ____________ providing they are separated by an insulator which, in a capacitor, is called a ____________.

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a-1186

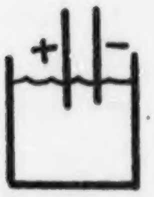
$(C=)\ \frac{Q}{V}$

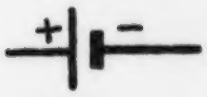
$(C=)\ \epsilon_o\, k \cdot \frac{A}{D}$

a-1142

kind
thickness
length

a-1098





a-1054

$\frac{\text{charge}}{\text{time (second)}}$

a-1010

electrons
at the other end

A·I·R ©1960

a-1005

easily allow the movement of free electrons (or, easily conducts current)

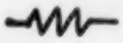
a-1049

proof-plane
proof-plane
electroscope (or, electrometer)

a-1093

voltage
current

a-1137



a-1181

store
capacitance
dielectric

A·I·R ©1960

A-1186

The formula for capacitance based on volts and charge is C = $\boxed{\$\qquad}$. The formula for capacitance based on the permittivity constant, the dielectric constant, area, and distance, is C = $\boxed{\$\qquad}$.

A-1142

A fixed resistor is made to provide a specified resistance. The resistance produced by a fixed resistor depends on the ______, ______, and ______ of the material used.

A-1098

Draw a simple battery, such as a voltaic cell. Indicate anode or cathode with symbols. Next to it, draw the symbol for a battery, also indicating the anode or cathode with symbols.

A-1054

Current is calculated as the number of charges passing a given point in a second. Using words, another way of saying this is that current = $\dfrac{\boxed{\qquad}}{\boxed{\qquad}}$.

A-1010

If a negatively charged object is touched to one end of a conductor, the ______ already in the conductor are repelled, which starts a flow of electrons. To maintain the flow of electrons, there must be a continuous supply of electrons at one end of a conductor and a means of escape $\boxed{*\qquad}$.

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A-1006

Most metals are ________ of electric charge. Copper wire for instance, is often used as a ________.

A-1050

One device used to create a charge of static ________ is called a Van de Graaf generator. Rather than rubbing amber with silk or rubber with fur to create a * ________ it is possible to use a * ________.

A-1094

To make a battery producing a different voltage, it would be necessary to try different materials as the plates or ________ and as the liquid or paste called the ________.

A-1138

The resistance of any material depends on the kind of material used, its thickness and its length. The longer the material, the ________ the resistance, but the thicker the material, the ________ the resistance.

A-1182

Capacitance equals coulombs per volt, or C = $ ________. A farad is the unit of measure of capacitance, but we usually use one-millionth of a farad, abbreviated $ ________.

A·I·R ©1960

a-1185

capacitance

$(C =) \epsilon_o k\frac{A}{D}$

a-1141

$\frac{2}{3}$

a-1097

anode

cathode

a-1053

negatively

negative

positive

a-1009

semiconductors

A·I·R ©1960

a-1006

conductors
conductor

a-1050

electricity
charge of static electricity
Van de Graaf generator

a-1094

electrodes
electrolyte

a-1138

more (or, greater)
less (or, lower)

a-1182

$(C =) \frac{Q}{V}$
m.f.d.

A·I·R ©1960

A-1185

The constants ϵ_o and k, representing the dielectric used, times the area, A, of the plates in meters, divided by the distance, D, between the plates in meters, is the formula for computing ☐ of a parallel plate capacitor. In symbols this would be C = ☐ $.

A-1141

For a material of uniform thickness, resistance is proportional to length of material. Decreasing the length of a wire by $\frac{2}{3}$ will decrease the resistance by ☐ #.

A-1097

In a circuit, the symbol for a battery is —|‖— . The long thin line indicates the positive terminal or ☐ and short heavy line indicates the negative terminal or ☐.

A-1053

An electric current consists of a flow of electrons, which are ☐ charged. For this reason we describe current as flowing from a ☐ terminal to a ☐ terminal.

A-1009

Some substances are neither good conductors nor insulators. They are known as semiconductors. Germanium is an example of a ☐.

A·I·R © 1960

A-1007

Some substances will not ordinarily conduct charges. These substances are called insulators. Paper is an example of an ________.

A-1051

When electric charges are at rest we call this * ________________.
When electric charges move they produce a flow of electric ________.

A-1095

To increase the current produced by a battery without changing voltage, we use the same material for the plates but ________ their area.

A-1139

If a material is a poor conductor, the resistance will be ________; that is, the kind of material used will affect the ________.

A-1183

In a parallel plate capacitor, we can increase capacitance by (increasing/decreasing) ________ the distance between plates or by (increasing/decreasing) ________ the area of overlap of the plates.

A·I·R ©1960

a-1184

distance
area of overlap
dielectric

a-1140

decreases
less

a-1096

voltmeter to the terminals of the battery

a-1052

electric current

a-1008

allow movement of electrons (or, conduct charge)

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(537)

a-1007

insulator

a-1051

static electricity
current

a-1095

increase

a-1139

greater (or, larger)
resistance

a-1183

decreasing
increasing

A·I·R ©1960

A-1184

Three factors influence the capacitance of a parallel plate capacitor: the ________ from one plate to the other, the * ________ of the plates and the kind of material, or ________, between the plates.

A-1140

Current flows easier through a wire of larger diameter than it does through a wire of smaller diameter. In other words, the thicker the conductor, the (greater/less) ________ the resistance.

A-1096

To measure the electromotive force of a battery we would attach a ** ________ ________.

A-1052

The movement of electrons along a conductor is known as an * ________.

A-1008

Insulators are substances which will not easily ** ________.

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